PERSONNEL RECOVERY: USING GAME THEORY TO MODEL STRATEGIC DECISION MAKING IN THE CONTEMPORARY OPERATING ENVIRONMENT

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by

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

PERSONNEL RECOVERY: USING GAME THEORY TO MODEL STRATEGIC DECISION MAKING IN THE CONTEMPORARY OPERATING ENVIRONMENT, by MAJ Marshall V. Ecklund, 126 pages.

The contemporary operating environment and recent increases in asymmetric tactics to counter the conventional military superiority of the U.S. presents significant operational challenges. Recovery forces are vulnerable conducting personnel recovery because the situation, not the military, dictates the terms of engagement. Thus, the central research question is: Given a report of the physical location of an evader, is the military using the most rational decision-making model to offset the predictable nature of traditional recovery activities? As a flexible and adaptive strategic decision-making tool, game theory offers a logical way to graphically represent and compare all strategy combinations in order to test the rationality of current recovery doctrine. After evaluating the generalized motives and capabilities of seven types of adversaries, in six cases the strategic costs of not recovering an evader outweighed the tactical costs of predictability. Deploying recovery assets is, more often than not, the optimal choice based on adversarial capabilities, ideology, motivation, and strategy. With a potentially devastating strategic vulnerability to hostage exploitation aimed at its legitimacy, credibility, and public will, the U.S. can ill afford not to recover those forced to evade. In this strategic context, the military's decision-making process with regard to personnel recovery is completely rational.

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ACRONYMS

COA	Course of action
COE	Contemporary operating environment
COMAP	Consortium for Mathematics and Its Applications
DOD	Department of Defense
EST	Eastern standard time
EV	Expected value
FM	Field manual
HR	Hostage rescue or hostage recovery
IO	Information operations
IP	Isolated personnel
JP	Joint publication
MDMP	Military decision-making process
NAR	Nonconventional assisted recovery
OIF	Operation Iraqi Freedom
PO	Pareto optimal
PR	Personnel recovery
RF	Recovery force
SOP	Standing operating procedure or standard operating procedure
SQ	Status quo
UAR	Unconventional assisted recovery
USSR	The Union of Soviet Socialist Republics

ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

The purpose of writing this thesis is twofold: first, to categorize the motivations and capabilities of various adversaries faced with the choice of capturing isolated personnel and second, to address how to determine the most rational decision for the United States (U.S.) with regard to conducting a recovery operation when faced with a generalized type of adversary. The author's qualifications for writing on this topic include professional military education and training in personnel recovery (PR) operations, formal education in mathematical modeling, and dedication of much time over the last three years to researching and writing on the subject of PR. While the focus of this thesis is specific to the issues facing PR operations, the findings will contribute to the overall decision-making process by operationalizing the concepts of game theory for use with problem solving and the military decision-making process (MDMP).

This thesis consists of five chapters. Chapter 1 includes an introduction, background, context of the problem and research question, assumptions, limitations and delimitations of the research, significance of the research, and a literature review. Chapter 2 presents an introduction and overview to the basic concepts behind game theory necessary to understand its use as a research methodology. Chapter 3 describes categories, capabilities, and motivations of various types of adversaries with regard specifically to PR scenarios and assigns course of action (COA) preferences when faced with the prospect of capturing isolated personnel (IP). Chapter 4 analyzes the preferences of U.S. and adversarial forces in order to apply game theory as a decision-making tool to determine the most rational choice for both sides in a scenario involving IP. Finally, chapter 5 presents the conclusions and recommendations based on the analysis in the previous chapter. A glossary immediately following chapter 5 lists the operational definitions of key terms necessary to understand the basics of game theory, PR, and applicable military doctrine.

Background and Context

A fundamental premise in the art of military decision making is to select a COA that offers the greatest promise of success or a COA that is most favorable to accomplish the mission in view of an adversary's capabilities or intentions. When developing plans, military commanders typically choose a decision-making style that is either analytic, intuitive, or a combination of the two. Analytic decision making approaches problems systematically through a thorough analysis of several possible solutions aiming to identify the best solution to a problem from among those considered. From the U.S. Army's perspective, the methodical analytic approach

> serves well for decision making in complex or unfamiliar situations by allowing the breakdown of tasks into recognizable elements. It ensures that the commander and staff consider, analyze, and evaluate all relevant factors. It may help inexperienced leaders by giving them a methodology to compensate for their lack of experience. The Army's analytical approach to decision making [sic] is Army problem solving . . . and the MDMP. . . . The analytic approach to decision making serves well when time is available to analyze all facets affecting the problem and its solution. However, analytic decision making consumes time and does not work well in all situations—especially during execution, where circumstances often require immediate decisions. (FM 5-0 2005, 1-6)

Preserving the lives of those participating in U.S.-sponsored activities and missions will continue to be one of the highest priorities of the Department of Defense (DOD). Therefore, DOD has a vested interest in conducting PR missions as effectively as possible, so that commanders and their staffs avoid unnecessarily placing further lives at risk in the process of recovery. Based on the rise in asymmetric threats and tactics and the predictability of the U.S. military's actions with regard to PR, current doctrine does not appear to optimally support continued PR mission successes. The military's institutional failures to learn from past disappointments against adversaries who employed guerrilla tactics and its proclivity to reinforce the perceived successes of its conventional supremacy are to blame. Optimal operational and strategic choices, based on distinct types of adversaries, should rationally guide MDMP. Quantitative game theory offers one such method to describe the motivations and capabilities of generalized categories of adversaries in order to deduce models for PR scenarios.

Vignette: Cuban Missile Crisis

Since game theory is theoretical in nature, throughout the thesis the author will refer to a vignette of the Cuban missile crisis to ground the theory in a commonly known case of strategic decision making. Building upon the analyses of Dr. Stephen J. Brams in "Game Theory and the Cuban Missile Crisis" and Ben Larson and Kurt Wiersma in *Fourteen Days in October: The Cuban Missile Crisis*, the author will use a scenario that took the world to the brink of nuclear disaster to ground the theory in something tangible.

In summary, by 1962 the Union of Soviet Socialist Republics (USSR) was desperately behind the U.S. in the arms race. Soviet missiles were only powerful enough to attack Europe, while U.S. missiles were capable of striking the entire Soviet Union. In May 1962, Soviet Premier Nikita Khrushchev conceived the idea of placing medium- and intermediate-range missiles in Cuba, thereby doubling the Soviet strategic arsenal and providing a credible deterrent to a potential U.S. attack against the Soviet Union. Ever since the failed Bay of Pigs invasion in 1961, Cuban President Fidel Castro felt a second attack was inevitable, and was looking for a way to defend his island nation from an attack by the U.S. Consequently, he approved of Khrushchev's plan to place Soviet missiles in Cuba (Brams 2001; Larson and Wiersma, 1997, 3).

The crisis began for the U.S. on 15 October 1962 when photographs taken from a U-2 reconnaissance aircraft the previous day revealed Soviet missiles under construction in Cuba. Early on 16 October, officers informed President John F. Kennedy about the missile installations, whereby Kennedy immediately organized a group of his twelve most important advisors to handle the crisis. When the U.S. discovered the missiles, Soviet commanders in Cuba were already prepared to defend the island if invaded by the U.S. (Brams 2001; Larson and Wiersma, 1997, 3-4).

The immediate goal of the U.S. was to remove the nuclear missiles. Faced with the fact that the missiles were already in Cuba, Kennedy ultimately considered two primary strategies to achieve this end. First, he contemplated a naval blockade or "quarantine" to prevent shipment of more missiles, possibly followed by stronger action to induce the Soviets to withdraw all of the missiles in Cuba. Second, he deliberated over launching a surgical air strike to destroy the missiles in Cuba, perhaps followed by an invasion of the island. From the Soviet perspective, the strategic choices centered its decision whether to withdraw or maintain its missiles in Cuba (Brams 2001). Using this real world vignette in the chapters that follow, the author will show how one can use game theory to explain the relationship between strategic decision-making dilemmas and the predictive forecasting possible with theoretical modeling.

<u>Problem Statement</u>

The second draft revision of Joint Publication (JP) 3-50, *Joint Personnel Recovery*, proposes redefining PR as "the sum of all military, diplomatic, and civil efforts to effect the recovery and reintegration of isolated personnel" (2004, GL-17). The draft revision further recommends that the term IP be redefined as "U.S. military, DOD civilian, and DOD contractor support (and others designated by the President or Secretary of Defense) who are separated (as an individual or group) from their unit while participating in a U.S. sponsored military activity or mission and are in a situation where they must survive, evade, resist, or escape" (GL-14).

Upon notification of a situation involving IP, the military's nondoctrinal standing operating procedure (SOP) for recovery via traditional means, formerly referred to as combat search and rescue, is to immediately assemble, organize, and launch an ad hoc recovery force (RF) to preclude capture and exploitation of the IP. Since the early 1990s, several adversaries have recognized an instinctive response and have attempted to exploit this predictability by baiting RFs into ambushes. PR is a unique military operation in that it is one of the few circumstances where the U.S. does not dictate the timing, location, or other terms of the situation. The only proactive elements of PR are training and general planning; everything else, especially the decisive effort to recover IP, is reactive and largely devoid of intricate shaping efforts.

Without the luxury of robust or well-developed shaping efforts to support traditional PR, one could argue that the U.S. military can no longer afford to offer an easily exploitable opportunity to adversaries who have recently honed tactics capable of leveraging the restrictions placed on those RFs that are unable to leverage the U.S.'s conventional superiority when operating in an improvised manner. As a result, the U.S. should reevaluate the current practicality of the process used to determine under what conditions one should launch an RF to facilitate PR.

Research Questions

The contemporary operating environment (COE) and the recent increase in asymmetric tactics to counter the U.S.'s conventional military superiority are the basis for primary question this thesis will answer. Doctrinally, few commanders will deploy an RF without first authenticating and verifying the location of the IP. If captured, recovering IP becomes the responsibility of hostage rescue forces. The time between the IP's authentication and capture bounds the focus of the research question. Given a report of the physical location of evading IP, is the PR community using the most rational decision-making model to offset the predictability of the U.S. military's traditional PR activities? Exploring five secondary questions facilitates answering this primary question.

The first secondary question addresses the feasibility of PR planners using game theory as a strategic tool to assist with strategic problem solving and the MDMP. If sufficient time is available to conduct a thorough analysis of all reasonable solutions to a tactical problem, then game theory might provide a way to graphically represent and compare information contained in portions of the commander's estimate of the situation.

The next secondary question deals with choosing between the two-person zero-sum game and the variable-sum game methodologies to analyze strategic choices. While most military applications of game theory use the simpler zero-sum approach, the unique circumstances of PR might lend themselves to a more precise and useful decision-making tool realized by employing variable-sum game theory.

The third secondary question pertains to determining the different types of generalized adversaries that the U.S. could likely face in the COE. With no established doctrinal standard for categorizing types of adversaries, this research will establish an undetermined number of possible adversaries based on a combination of military capabilities and ideologies with regard to capturing IP. Once categorized, the next task will be to assign values representative of each adversary's strategy preferences based on the organization's capabilities, ideology, motivations, and strategy. These preferences assume an adversary can correctly ascertain the U.S.'s military's preferences for recovering IP based on the doctrine, capabilities, freedom of maneuver or relative strength, culture, historical predictability based on past PR situations, and strategy.

The fourth secondary question centers on the problem of how to determine reasonably accurate utility values needed to apply utility theory to a variable-sum, partial-conflict game representative of a PR scenario. In order to apply a meaningful mixed-strategy solution to a particular scenario that is not solvable using pure strategies, one must apply cardinal values to both players' preferences. For a complex military situation such as PR, the development of a quantitative scale of military worth that is the same for both players represents the greatest challenge in using mixed-strategy solutions.

Finally, the fifth secondary question asks if there are scenarios requiring mixed strategies, where it might be feasible for PR planners to employ either Nash arbitration or the concept of strategic moves to identify the most efficient solution for a given scenario. If such a scenario does exist, determining how an arbitrator could schedule each player to play the strategies in the correct proportions and at the right times to arrive at the Nash arbitration point should prove to be the tougher problem.

Significance of the Research

Using models representative of the preferences of both the U.S. and a generalized adversary, one can apply game theory to determine the most rational decision from both perspectives and the most likely outcome of the game. Deriving preferences for the U.S. military and different categories of adversarial forces, this thesis will challenge the rationality of the facet of U.S. military culture that drives seemingly emotional and impulsive responses to situations involving IP. If game theory models indicate that hastily launching ad hoc RFs is a suboptimal solution, this thesis will recommend specific solutions to recover IP that support a more combat-focused, offensive-minded, and utility-driven process for analyzing PR. If game theory models show that the U.S. is, in fact, using the most rational decision-making process, to the best of the author's knowledge this thesis will be the first quantitative analysis to validate the military's doctrine and rationale for PR. In either case, the thesis will show that game theory has wider application in the decision-making process during COA analysis and comparison.

Assumptions

There are several underlying propositions that the author must accept as true in order to proceed with this research. First, the author assumes that one can deduce different categories of adversaries that sufficiently capture the generalized capabilities and motivations of any particular group that might fall into that category; no adversary is so unique that he does not fit, to some extent, into a predetermined category. Having articulated those capabilities and motivations, a subsequent assumption is that the author can measure adversarial preferences with regard to IP, given various COAs from which to choose. This implies that the author will be able to move beyond any cultural, cognitive, or perceptual bias in order to determine adversarial COA preferences from an opponent's perspective.

Along this same vein, this thesis' argument will rely heavily on the rational actor model of decision making. While clearly some adversarial actions may seem irrational from a Western perspective, the author will make every effort to ensure that the bias towards rational actions in accordance with Western norms is not the perspective from which the author views an adversary's choices. When generalizing motivations and capabilities of various groups, this will be somewhat easier, since the model described will not specifically apply to any one cultural or ethnic group. A common fallacy in applying rationality to game theory is that in choosing between two alternatives, if a player does not choose the COA with the higher utility, one could erroneously assume that the player is acting irrationally. Actually, the incongruity comes from the fact that the player has made a choice inconsistent with the choices from which he determined his utilities, his preferences have changed, or he cannot assign consistent utilities to his preferences due to indifference or some other factor (Straffin 1996, 53).

Furthermore, this thesis assumes that the rise of asymmetric threats in the COE has somehow changed the conditions under which the U.S. military conducts PR missions. The author further assumes that future adversaries will increasingly employ asymmetric tactics in order to exploit the predictability of the U.S. military's PR missions. Since the conventional battlefield has become inhospitable to forces facing the U.S., this assumes asymmetric tactics will continue to offer future adversaries the highest probability of success, and increases the desire of weaker adversaries to acquire hostages and use the media to attack America's perceived center of gravity--the will of its populace and its reluctance to sustain casualties. Possible means of exploiting asymmetries include baiting RFs into ambushes and capturing IP to use as tools for propaganda or negotiations.

Literature Review

The most significant limitation of this research is the gap in available information on the subjects of PR and game theory and the use of variable-sum game theory for military decision making. To date, the author has not positively identified a single key work, be it a book, article, research paper, study, or thesis, which specifically concentrates on the application of game theory to PR. However, while the initial research for this thesis revealed numerous related materials available for use, including books, articles, internet sources, and numerous subject matter experts on the subject of game theory, surprisingly the military applications of game theory has received little attention. The military has used game theory since its inception, but has done very little with anything other than zero-sum analysis for application to its decision-making process.

As early as 1954, U.S. Army Colonel (Retired) Oliver Haywood suggested in his article “Military Decisions and Game Theory” that game theory techniques were relevant to preparing the military commander’s estimate of the situation. Most recently, U.S. Army Lieutenant Colonel Gregory Cantwell’s School for Advanced Military Studies monograph, “Can Two Person Zero Sum Game Theory Improve Military Decision-Making Course of Action Selection?” attempted to operationalize game theory to COA selection using a ten-step method for determining the values of military worth for a two-person zero-sum game. Cantwell’s monograph was the only identified example of previous research where an author was able to present a reasonable method for assigning values of military worth to COAs or strategies to solve zero-sum games.

The variable-sum game has apparently been more elusive for researchers. In only one case was the author able to locate a work that prescribed a variable-sum model to evaluate a military mission. U.S. Army Major Carlos Pérez dedicated a chapter in his master's thesis, "Anatomy of a Hostage Rescue: What Makes Hostage Rescue Operations Successful?" to assigning utility values to different categories of both hostage rescue forces and hostage takers for use with game theory modeling. While not specifically or doctrinally PR, Pérez' analysis is very similar to the methodology necessary to assess PR scenarios and provides a possible guide for determining cardinal values needed to solve PR situations requiring mixed-strategy solutions.

Of the numerous sources on game theory in general, the author limited primary consultation to a few noteworthy subject-matter experts. Dr. Frank R. Giordano (Brigadier General, U.S. Army, Retired), a professor specializing in math modeling at Naval Postgraduate School, personally provided a wealth of knowledge on the mechanics and military application of game theory. His textbook, *A First Course in Mathematical Modeling*, coauthored with Dr. Maurice D. Weir and William P. Fox, provided a foundation for the practical application of math modeling.

Dr. Stephen J. Brams, a professor of politics at New York University, is the author or coauthor of no fewer than thirteen books involving applications of game theory and social choice theory. Approaching game theory from a political scientist's perspective, his most relevant works to this research were *Superpower Games: Applying Game Theory to Superpower Conflict* and "Game Theory and the Cuban Missile Crisis."

Dr. Phillip D. Straffin, an interdisciplinary professor at Beloit College, wrote *Game Theory and Strategy* on behalf of The Mathematical Association of America. Written by a professional mathematician with the purpose of making some important mathematical ideas interesting and understandable to a large audience, including laymen, the book covers many topics not usually covered in standard textbooks. However, textbooks by the Consortium for Mathematics and Its Applications (COMAP), such as *For All Practical Purposes: Math Literacy in Today's World*, provided a solid basis for understanding the essentials of game theory and proved indispensable in this research effort.

Limitations

The current trend in the focus of scholarly works focused on PR primarily address operating "jointly" to effect recovery, without regard to changing doctrine or organizations to address the changing nature of the asymmetric threats in the COE. If successful, this thesis will make significant contributions to the PR community by evaluating the rationality of U.S. PR doctrine given the predictable nature of recovery operations, and by offering a logical method to graphically represent and compare all strategy combinations, in order to select an optimal strategy. However, due to time constraints, the thesis research is limited to four months in order to complete the thesis within a prescribed period.

Delimitations

In prescribing a more rational decision-making model, this thesis will initially analyze only traditional methods of PR, which will exclude both covert and clandestine methods of recovery as strategic choices. While viable methods of recovery with potentially higher probabilities of mission success exist, special operations forces and other government agencies exclusively execute clandestine or covert PR activities and are extremely limited in their capabilities. This thesis will consider the joint PR community as one entity, instead of addressing the particulars of any specific service or branch. Additionally, the intent of this thesis is to present models of recovery that are applicable to any geographic region, all types of terrain, and both urban and rural environments.

The period of examination will be from 1990 to the present in order to restrict research to relevant features and trends typified in the COE. Additionally, this thesis will only address evaders and will not consider captured IP. Military doctrine categorizes captured IP as hostages, placing the rescue of those hostages within the doctrine and tactical problem of hostage rescue forces--an entirely different mission set with a different set of problems and strategic choices for the U.S. and the capturer.

Final Note to the Reader

Before proceeding further with this thesis, it will help to relax and be patient. As a specialty within mathematics, game theory is still relatively new, but holds great potential in uncharted areas of military application. While the material and concepts may seem confusing at first, be patient with them. Authors have dedicated entire books to the subject of game theory, so the reader should not expect that chapter 2 would contain everything necessary to understand the concepts completely--the author only intended to provide a basic background so that a reader could understand the basis of the thesis' methodology. The author struggled to apply a useful dose of practical examples to reach a broader audience, often foregoing mathematical and technical explanations for brevity.

Assuming that most readers will have minimal or no background in the military application of game theory to decision making, the author attempted to explain things as simply as possible. The thesis targets a very specific audience of DOD personnel in the PR community dedicated to mitigating risks associated with preserving the force. Finally, the reader should keep in mind that game theory is not difficult to learn; it is only difficult to learn quickly. The practical application of theory is not always easy to visualize with only one reading. Just as one cannot master the MDMP after one practical exercise in a training environment, one will not master game theory as it relates to PR after just one reading of this thesis. Nonetheless, just as with almost anything difficult, with practice comes competence. For those who choose to understand its military utility, game theory provides a powerful tool to assist in military decision making.

CHAPTER 2

RESEARCH METHODOLOGY: AN INTRODUCTION TO GAME THEORY

John von Neumann and Oskar Morgenstern first introduced the theory of games in their 1944 book, *Theory of Games and Economic Behavior*. Within a given set of strategies, game theory attempts to determine the optimal choice of strategy for players competing to optimize their outcomes by controlling the course of events. Game theory uses mathematical modeling to study situations involving both conflict and cooperation. The difficulty with game theory analysis, when compared to standard operational analysis, is that one must consider the simultaneous optimization of strategy choices for several interacting players, where the strategy choices of all other players affect each of the individual strategy choices of all other players.

When applying game theory, players are simply those people, organizations, or countries that are involved in varying degrees of conflict and cooperation. The players have before them two or more COAs to apply to given situations, or strategies. Each player's choice of one strategy over all others results in an outcome, which is nothing more than the consequences of that choice. A fundamental assumption of game theory is that of the available strategies, players will favor one more than the other(s), which demonstrates a player's preference. Game theory attempts to analyze the rational choice of strategy selection, which is nothing more than selecting a strategy that will result in that player's highest level of satisfaction (COMAP 1996, 561).

Where game theory differs from individual decision making is that in the strategic decision making replicated by game theory, the ultimate outcome of a situation depends on the choices of all of the players involved. Because players are often involved in conflict because of dissimilar goals or objectives, they do not necessarily cooperate when selecting strategies. In football, for example, an offensive gain of one yard is a defensive loss of one yard--the teams' strategies are noncooperative by nature. Football is an example of a two-person game of total conflict, in which one team (in the strategic sense, a team is considered a player) wins and the other team loses, so cooperation is never beneficial to either team (COMAP 1996, 563). In other two-person encounters of partial conflict, players can benefit from cooperation, but may have strong incentives not to cooperate. Most interactions arguably involve a mix of cooperative and noncooperative behavior (COMAP 1996, 563).

Two-Person Total-Conflict (Zero-Sum) Games

Pure-Strategy Solutions

Figure 1 is an example of a two-person zero-sum game solvable using pure strategies, or single strategies that one should play with certainty. A zero-sum game is one in which the payoff to one player is the negative of the corresponding payoff to the other player, so the sum of the two payoffs is always zero. The payoff matrix makes the application of game theory in its strategic form possible by showing the set of players, the pure-strategy spaces, and the payoff function assigned to each strategy. In figure 1, the numbers assigned to the four payoff strategy spaces are ordinal values, representing preferences to outcomes; it is the ordering of the numbers, not their absolute or relative magnitude, which matters. The row player has the choice of strategies "A" or "B," and the column player has strategy choices of "C" or "D." In total-conflict games, the value in each payoff strategy space represents the gain to the row player (for example a positive value of 4). There is no need to show the values for the column player in zero-sum games because the column player's loss is always the negative of the row player's corresponding payoff (a negative value of 4, or -4, keeping with the previous illustration) (Straffin 1996, 50).

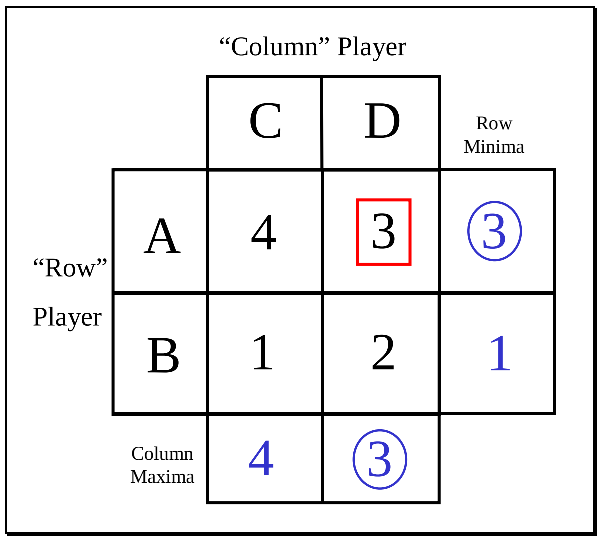

Figure 1. Two-Person Total-Conflict Game Matrix Solved Using Pure Strategies

In zero-sum games, the row and column player's strategies are in total conflict. The row player desires to maximize his gains, while the column player wants to minimize the row player's gains. A pessimistic row player would identify the lowest possible value in each row and then choose the strategy corresponding to the greatest of those guaranteed values. Using a worst-case analysis, the 3 in the column labeled "Row Minima" represents the maximin solution, or the row player's highest of the minimum values recorded in each of the table's rows. The strategy corresponding to choosing the maximin solution is the maximin strategy. The worst-case analysis for the column player would be the opposite. The 3 in the row labeled "Column Maxima" represents the column player's minimax solution, or the minimum of the maximum values recorded in each of the table's columns. A pessimistic column player would identify the greatest possible value in each column, and then choose the strategy corresponding to the lowest of those guaranteed values. The minimax strategy corresponds to the strategy of choosing the minimax solution (COMAP 1996, 564-565).

Continuing with the example in figure 1, the row player would select a pure strategy ensuring a gain of three or more (Strategy A), while the column player would select a pure strategy ensuring a loss of no more than three (Strategy D). Since both the maximin and minimax values are the same, the outcome of (3 , -3) is a saddlepoint, or the unique numerical entry that is simultaneously the largest column value and smallest row value. In games with saddlepoints, the best-guaranteed outcomes come from players' worst-case analyses. There is no need for secrecy in games with saddlepoints, so prior knowledge of an opponent's move offers no exploitable advantage (COMAP 1996, 566).

For two-person games, the value of the game and the two optimal strategies are the solution of the game. Every matrix game has such a solution according to the minimax theorem proved by von Neumann in 1928 (Straffin 1996, 18). The minimax theorem "guarantees that there is a unique game value, and an optimal strategy for each player, so that either player alone can realize at least this value by playing this strategy, which may be pure or mixed" (COMAP 1996, 578-579). By definition, when using these optimal strategies, the unique value of the game "v" guarantees that "1) if the row player uses his optimal strategy, the row player's expected payoff will be $\geq v$, no matter what the column player does, and 2) if the column player uses his optimal strategy, the row player's expected payoff will be ≤ v, no matter what the row player does" (Straffin, 18). The value of the zero-sum game described in figure 1 is 3; the row player guarantees earning no less than 3 when choosing his maximin strategy, and the column player guarantees that he will lose no more than 3 when choosing his minimax strategy.

Mixed-Strategy Solutions

Since most competitive games do not have a saddlepoint, players should keep their strategy choices secret, so that other players do not use this knowledge to gain an advantage. Players should conceal their strategy selections until the encounter actually takes place--when it is too late for an opponent to alter his choice. In repeated games, a player will want to vary his strategy selection in order to surprise an opponent and might achieve success through bluffing or deception (COMAP 1996, 569).

When players have one strategy that is always more advantageous, or at least as advantageous, as all other strategies, they have a dominant strategy; the opposite is true for dominated strategies. Whereas ordinal utilities are adequate for determining dominance and saddlepoints, the ratios of differences between the values are more significant for precise analysis and are essential in zero- and variable-sum games requiring mixed-strategy solutions. Utility theory, the science of assigning numbers to outcomes in a way that reflects degrees of preference, uses an interval scale that recognizes both the order of the numbers and the ratios of differences between the values. Numbers reflecting preferences on an interval scale are cardinal values. The values necessary to obtain a meaningful solution to any mixed-strategy game must be cardinal. However, when compared to ordinal values, cardinal utilities are significantly more difficult to determine accurately (Straffin 1996, 50-52).

A common fallacy when using utility theory is to assume that if “Player A’s” utility for an outcome is higher than “Player B’s,” then Player A values that outcome more than Player B. For example, if a particular outcome were a one-hundred dollar bill for each player in a two-person game, an extremely wealthy player would probably not value this outcome the same as a penniless player--even though the utility of one-hundred dollars is exactly the same for both players. There is currently no reliable method of comparing two different players’ utilities with precision, because each player determines his values on a personal level to assist in determining how to make choices among alternatives. With such subjective values, both endpoints of a cardinal utility scale are usually arbitrary (Straffin 1996, 50-54).

Figure 2 represents a two-person total-conflict game between a pitcher and batter. This example assumes that a pitcher can only throw two pitches--fastball and curve. The batter has known batting averages against each pitch when guessing correctly and incorrectly; the batter would like to maximize his payoff not knowing what the next pitch will be. By examining the row minima, the batter could guarantee hitting at least .200 if he played his maximin strategy and always guessed fastball. The pitcher, on the other hand, could ensure that the batter hits .300 or less by throwing nothing but fastballs when applying his minimax strategy.

There is no saddlepoint or dominance in this game, and both players would like to win as much of the .100 gap (difference between .200 and .300) as possible--the batter desires an average of .200 or more, while the pitcher wants to hold the batter to .300 or less. While it might appear that each player could outguess the other, there is no pitch or guess that is always advantageous; neither player would want to offer the other an advantage by playing a single strategy with certainty. The most rational plan would be to use a random device to decide which strategy to choose. Such a plan allows both players to do better by applying the concept of a mixed strategy--not by trying to anticipate the other player's strategy (COMAP 1996, 570-572; Straffin 1996, 13).

		Pitcher		
		Throw Fastball	Throw Curve	Row Minima
Batter	Guess Fastball	.300	.200	.200
	Guess Curve	.100	.500	.100
	Column Maxima	.300	.500	

Figure 2. Batting Averages in a Baseball Duel
Source: COMAP, *For All Practical Purposes* (New York: W.H. Freeman, 1996), 570.

A mixed strategy is a particular randomization of all of a player's pure strategies according to optimal fixed probabilities. The probability of a player's pure strategy indicates the frequency with which to play that pure strategy, but using a mixed strategy, one describes the outcome in terms of the probabilistic notion of an expected value (EV). The EV of a set of payoffs is simply the weighted average of those payoffs, where the weights are the probabilities that each payoff will occur. Using the principle of EV, if one knows that an opponent will play a given mixed strategy and will continue to play that strategy regardless of the friendly strategy selection, one should select a strategy with the largest EV. The EV of obtaining payoffs $a_1, a_2, \ldots, a_k$ with respective probabilities of $p_1, p_2, \ldots, p_k$ is $p_1a_1 + p_2a_2 + \ldots + p_ka_k$ (Straffin 1996, 13).

		Pitcher		
		Throw Fastball	Throw Curve	
Batter	Guess Fastball	.300	.200	$(1\text{-}x)$
	Guess Curve	.100	.500	(x)
		$(1\text{-}y)$	(y)	

Figure 3. Baseball Duel with Known Probabilities
Source: COMAP, *For All Practical Purposes* (New York: W.H. Freeman, 1996), 578.

Figure 3 shows both players' probabilities from figure 2 and the unknown EVs that each player must determine. The batter desires to select some mix of guesses that the pitcher cannot exploit. To find this mixed strategy, the batter will determine the pitcher's optimal strategy with probabilities x when the batter follows the pure strategy of "Guess Curve" and $(1\text{-}x)$ when the batter follows the pure strategy of "Guess Fastball," where x is a percentage between zero and one. Using the formula for EV, when minimizing the hitter's batting average (BAT AVG), the pitcher's pure-strategy EVs would be:

$$\text{BAT AVG} \leq \text{EV (Throw Fastball)} = .300(1\text{-}x) + .100(x) = .300\text{-}.200x$$

$$\text{BAT AVG} \leq \text{EV (Throw Curve)} = .200(1\text{-}x) + .500(x) = .200\text{+}.300x$$

When the batter uses the method of equalizing expectations, he can "equalize" the pitcher's two pure-strategy expectations by setting the two EVs equal to each other, and then solving for *x*. This ensures that the pitcher will not be able to take advantage of the batter's mixed strategy.

$$\text{EV (Throw Fastball)} = \text{EV (Throw Curve)}$$

$$.300\text{-}.200x = .200+.300x$$

$$.100 = .500x$$

$$x = .20 \text{ or } 20\% \ (x = \text{optimal percentage to choose Guess Curve})$$

$$(1\text{-}x) = .80 \text{ or } 80\% \ ((1\text{-}x) = \text{optimal percentage to choose Guess Fastball})$$

Regardless of the pitcher's strategy selection, if the batter plays his optimal mixed strategy of guessing curve twenty percent of the time, and guessing fastball the remaining eighty percent {.20 Guess Curve, .80 Guess Fastball}, the batter is assured of earning, on average, a batting average of no less than the value of the game. The batter determines that .260 is the mixed-strategy value of the game by substituting the value for *x* into either of the pitcher's pure-strategy EVs:

$$\text{EV (Throw Fastball)} = .300\text{-}.200x \quad \text{or} \quad \text{EV (Throw Curve)} = .200+.300x$$

$$.300\text{-}.200(.20) \quad \text{or} \quad 200+.300(.20)$$

$$.260 \quad \text{or} \quad .260 = \text{the value of the game}$$

Next, the pitcher must follow the same process to determine his optimal mixed strategy, which is different from that of the batter. The pitcher desires to throw some combination of pitches that the batter cannot exploit. To find the pitcher's mixed strategy, the pitcher will determine the batter's optimal strategy with probabilities y when the pitcher follows the pure strategy of Throw Curve and (1-y) when the pitcher follows the pure strategy of Throw Fastball, where y is also a percentage between zero and one. Using the same formula for EV, when maximizing his batting average, the batter's pure strategies EVs would be:

$$\text{BAT AVG} \geq \text{EV (Guess Fastball)} = .300(1-y) + .200(y) = .300-.100y$$

$$\text{BAT AVG} \geq \text{EV (Guess Curve)} = .100(1-y) + .500(y) = .100+.400y$$

Just as before, when the pitcher equalizes the expectations of the batter's two pure-strategy EVs, the batter is unable to take advantage of the pitcher's mixed strategy. Setting the two pure-strategy EVs equal to each other yields the solution for y:

$$\text{EV (Guess Fastball)} = \text{EV (Guess Curve)}$$

$$.300-.100y = .100+.400y$$

$$.200 = .500y$$

$$y = .40 \text{ or } 40\% \ (y = \text{optimal percentage to choose Throw Curve})$$

$$(1-y) = .60 \text{ or } 60\% \ ((1-y) = \text{optimal percentage to choose Throw Fastball})$$

Regardless of the batter's strategy selection, if the pitcher follows his optimal mixed strategy of throwing curves forty percent of the time and fastballs the remaining sixty percent {.40 Throw Curve, .60 Throw Fastball}, the pitcher will not allow, on average, a batting average greater than the value of the game. The pitcher determines the same mixed-strategy value of the game of .260 by substituting the value for y into either of the batter's EVs using pure strategies:

$$EV\ (\text{Guess Fastball}) = .300\text{-}.100y \quad \text{or} \quad EV\ (\text{Guess Curve}) = .100\text{+}.400y$$

$$.300\text{-}.100(.40) \quad \text{or} \quad .100\text{+}.400(.40)$$

$$.260 \quad \text{or} \quad .260 = \text{the value of the game}$$

The solution of the game is the value of the game (.260), the pitcher's optimal mixed strategy {.60 Throw Fastball, .40 Throw Curve}, and the batter's optimal mixed strategy of {.80 Guess Fastball, .20 Guess Curve}. The outcome of .260 occurs when either the batter selects his optimal mixed guessing strategy or the pitcher selects his optimal pitching mixed strategy; the same is true with every two-person zero-sum game. There is a noticeable similarity between the concept of equalizing expectations to solve for a mixed-strategy value of the game and using saddlepoints to determine a pure-strategy game's value. However, one would always want to first check for a saddlepoint, and then attempt to reduce the game by assessing dominance before trying the method of equalizing expectations (Straffin 1996, 19). While two-person zero-sum games assume total conflict and a bipolar equivalency of gain and loss at every outcome, this does not reflect the reality of games characterized by partial conflict.

Two-Person Partial-Conflict (Variable-Sum) Games

Pure-Strategy Solutions: Ordinal Values

Two-person partial-conflict games are variable-sum games in which the sum of payoffs in each of the four payoff strategy spaces varies, and does not necessarily sum to zero as in zero-sum games. Invariably, in partial-conflict games there are some reciprocal gains both players can realize through cooperation, but this is often improbable in the absence of either good communication or trust. When trust or communication is poor, the condition is set for a noncooperative game, whereby no binding agreement is possible or enforceable. Even in instances allowing communication, there is no assurance that a player can trust another player to choose the particular strategy that he promised to select. Self-interests may actually result in choices that yield lower payoffs than could have been achieved through cooperation (COMAP 1996, 579).

To illustrate this point, one could consider a nuclear arms race between two countries that can independently select between one of two strategies: (1) arm in preparation for possible war (noncooperation) or (2) disarm or at least negotiate an arms-control agreement (cooperation). Players rank order their preferences for the four outcomes from one to four (four being the most preferred); one can model the arms race by the payoff matrix shown in figure 4. While not an issue in this example, modeling the infrequent instances where strategy choices are so different as to preclude having a preference, or when a player is indifferent to some of the choices (a tie), is not possible.

		“Column” Country	
		Arm	*Disarm*
“Row” Country	Arm	2 , *2*	4 , *1*
	Disarm	1 , *4*	3 , *3*

Figure 4. Arms Race Payoff Matrix Using Ordinal Values
Source: COMAP, *For All Practical Purposes* (New York: W.H. Freeman, 1996), 581.

In variable-sum games, the first number (in normal font and red) in a given strategy space is always the row player's value, and the second number (in italic font and blue) is always the column player's value (Row value, *Column value*). Since these payoffs are ordinal values, they do not indicate the degree to which a player prefers one outcome to another, only that one is relatively better than another. The worst outcome of 1 for both countries occur when disarming while the other country arms, because the country arming will receive its best outcome of 4 and achieve a significant advantage over the disarming country. The second best outcome for both countries of (3 , *3*) occurs when both countries agree to negotiate an arms-control agreement and save huge amounts of national resources in the process. The second worst outcome of (2 , *2*) occurs when both countries spend huge amounts of money investing in arms, which results in an environment comparatively no more secure than if both countries had disarmed (COMAP 1996, 580-582).

When determining its strategy, "Row Country" must examine two cases. First, if "Column Country" selected its "Arm" strategy, Row Country must select from the two remaining payoffs of 1 or 2. After removing Column Country's unselected strategy of "Disarm" to simplify this explanation, figure 5 graphically depicts Row Country's selection of the higher payoff of 2 (the row player's vertical red arrows always point to the higher payoff). On the other hand, if Column Country selected its Disarm strategy, then Row Country must select from the remaining two payoffs of 3 or 4. Again, after removing Column Country's unselected strategy of Arm for simplicity of explanation, figure 6 shows Row Country's rational choice of selecting the higher of the two remaining payoffs. In both cases represented in figures 5 and 6, Row Country's strategy selections of Arm resulted in more desirable outcomes that its Disarm strategies. Arm is Row Country's dominant strategy (COMAP 1996, 582).

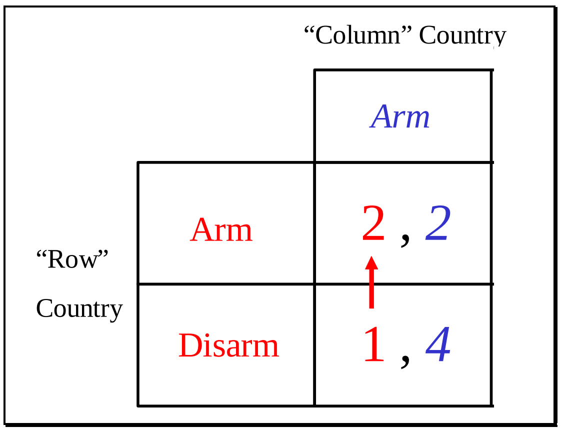

Figure 5. Row Country Strategy Selection if Column Country Arms

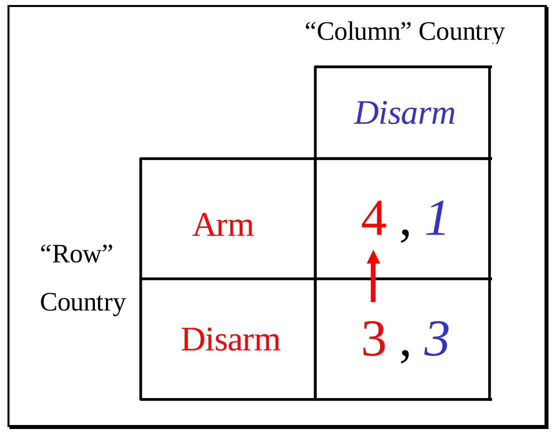

Figure 6. Row Country Strategy Selection if Column Country Disarms

Using the same logic to explain Column Country's perspective of the situation, if Row Country selected its Arm strategy, Column Country must select from the two remaining payoffs of 1 or 2. Figure 7 graphically depicts Column Country's selection of the higher payoff of 2 (the column player's horizontal blue arrows always point to the higher payoff). If Row Country selected its Disarm strategy, then Column Country must select from the remaining two payoffs of 3 or 4. Figure 8 shows Column Country's rational choice of selecting the higher of the available payoffs. As was the case with the Column Country, figures 7 and 8 show that the Row Country has a dominant strategy of Arm, always resulting in a more desirable outcome than its dominated strategy of Disarm (COMAP 1996, 582).

		"Column" Country	
		Arm	*Disarm*
"Row" Country	Arm	2 , *2*	4 , *1*

Figure 7. Column Country Strategy Selection if Row Country Arms

		"Column" Country	
		Arm	*Disarm*
"Row" Country	Disarm	1 , *4*	3 , *3*

Figure 8. Column Country Strategy Selection if Row Country Disarms

This analysis shows that when each country attempts to maximize its own payoffs independently (noncooperative game), each country will rationally select its strategy of Arm, resulting in a payoff of (2 , *2*). Only with mutual strategies of disarmament can both countries gain the more preferred outcome of (3 , *3*), but this maximin solution is unstable and difficult to attain when playing noncooperatively. The result of both players choosing their dominant strategies is a Nash equilibrium solution. Equilibrium outcomes in variable-sum games correspond to saddlepoints in zero-sum games; just as there are zero-sum games without saddlepoints, there are variable-sum games without pure-strategy equilibriums (Straffin 1996, 66).

In figure 4, the outcome of (2 , *2*) is a Nash equilibrium solution. One arrives at this Nash equilibrium when none of the players can benefit by unilaterally switching strategies. Assuming the other player makes no strategy change, if either player unilaterally decided to switch from its strategy of Arm, the result would be a loss of one unit of payoff. This choice is not rational, and deters both countries from leaving the point of Nash equilibrium (COMAP 1996, 582). However, in a purely economic sense, one should not accept a solution to the game if there is another solution that would benefit all players.

The more preferred, and highly unstable outcome of (3 , *3*) gives both players higher payoffs than the unique Nash equilibrium outcome. While the Nash equilibrium identifies the most likely noncooperative outcome, this result does not imply that the outcome is always the game's most efficient, or Pareto optimal (PO), solution. A game's outcome is PO if there is there are no other outcomes that give both players higher payoffs, or give one player the same payoff and the other player a higher payoff; an outcome is non-Pareto optimal (or Pareto inferior or Pareto inefficient) if such outcomes exist. Whereas every outcome in a zero-sum game is PO, this does not typically hold true for a variable-sum game (Straffin 1996, 68). While both players will desire a PO outcome, if at (3 , *3*) in this example, both countries would be tempted to cheat in order to gain an advantage by secretly arming themselves; the country that reneged first by pursuing its strategy of Arm would obtain its most preferred payoff of 4. One can escape from the noncooperative Nash equilibrium position when incentives are applied or when playing a game repeatedly. Setting credible patterns of cooperative rewards and noncooperative penalties is another way to ensure cooperation and deter the violation of agreements (COMAP 1996, 583).

Pure-Strategy Solutions: Cardinal Values

One weakness in the previous model of the nuclear arms race is that assigning ordinal values to outcomes does not accurately convey the relationships between the various preferences. Using a strategic game commonly known as the prisoner's dilemma, one can apply cardinal values representative of years in prison to illustrate the degrees of preference between strategic choices. The nuclear arms race example was actually the exact same prisoner's dilemma, only modeled with ordinal values and a different strategic situation. As noted earlier in the introduction of utility theory, comparing players' utilities with precision is complicated because each player values similar things differently. In the example of the prisoner's dilemma, both players may not equally value the utility of one year in prison, but with no method to compare each player's personal outlook on values of prison time, this analysis will assume that both players value time in prison the same.

The prisoner's dilemma is the story of two criminals whom authorities interrogate separately after arresting them for committing a crime. Each knows that if neither of them talks, the case against them will be weak and authorities will convict and punish them for lesser charges warranting only one year in prison. If both confess, each will get ten years in prison. If only one confesses and testifies against the other, the uncooperative prisoner will receive fifty years, while the cooperative prisoner will get parole. Recalling that cardinal values recognize both the order of the numbers and the ratios of differences between the numbers, the differences between the least preferred outcomes of 1 and 2 in the arms race example is much less meaningful than the comparison of the two least preferred utilities of ten and fifty years in prison. When comparing cardinal values, one can obtain a more accurate representation of the differences between preferences (five times greater when comparing fifty years to ten) instead of the uniform distribution of preferences found using an ordinal scale. Figure 9 illustrates the structure of the payoff matrix for this game (in this illustration, smaller numbers representative of fewer years in prison are more preferred than larger numbers).

		“Column” Prisoner	
		Confess	*Don’t Confess*
“Row” Prisoner	Confess	10 , *10*	0 , *50*
	Don’t Confess	50 , *0*	1 , *1*

Figure 9. Payoff Matrix for the Prisoner’s Dilemma (Cardinal Values)

If both prisoners acted rationally, they would both chose their dominant strategy of “Confess” in order to maximize their payoff. Such rational action would result in both prisoners going to jail for ten years (10 , *10*), and is the game’s non-Pareto optimal Nash equilibrium. For both prisoners “Confess” dominates “Don’t Confess,” even though the mutual-Confess outcome (10 , *10*) is worse for both prisoners when compared to the mutual-Don’t Confess outcome (1 , *1*). As stated earlier, dominant strategies in games of noncooperation and simultaneous moves will not always guarantee the best payoff.

If either prisoner unilaterally decided to switch his strategy to Don’t Confess, the result for the prisoner who changed would be forty additional years in prison (0 , *50*) or (0 , *50*), assuming that the other prisoner makes no strategy change. This choice is clearly not rational, and deters both prisoners from leaving the Nash equilibrium (10, *10*). Even if both prisoners had discussed the mutual benefits of not confessing before their capture, the outcome is still unstable. If the “Row Prisoner” believed that the “Column Prisoner” would hold up his end of the bargain by not confessing, the Row Prisoner’s incentive to confess in order to obtain the more desirable payoff of being set free would be tempting. Each prisoner would be enticed to go back on his word and pursue a strategy of Confess.

Mixed-Strategy Solutions: Cardinal Values

As previously discussed, there are some variable-sum games without pure-strategy equilibriums. If there were no conservative maximin strategies or dominant strategies that offer a stable outcome (Nash equilibrium), neither player would want to play a single strategy with certainty. Similar to the example of the two-person total-conflict game between the pitcher and batter, calculating a mixed-strategy equilibrium point for a variable-sum game requires a concept similar to equalizing expectations.

As with analyzing any game requiring a mixed-strategy solution, cardinal values are essential to meaningful results. In the case of a variable-sum mixed-strategy solution, players use a combination of strategies according to certain fixed probabilities called prudential strategies. A prudential strategy requires the analysis of two separate constant-sum (equivalently zero-sum) games for both the row and column players. The row player's payoffs are the basis for the row player's game; the row player maximizes while the column player foregoes his payoffs in order to attack, or equalize, the row player. Likewise, the column player's payoffs are the basis for the column player's game; the column player maximizes while the row player foregoes his payoffs in order to attack the column player.

Consider the hypothetical game in figure 10 with cardinal values and no Nash equilibrium, and the equivalently zero-sum games in figures 11 and 12 representing the respective row and column player's games:

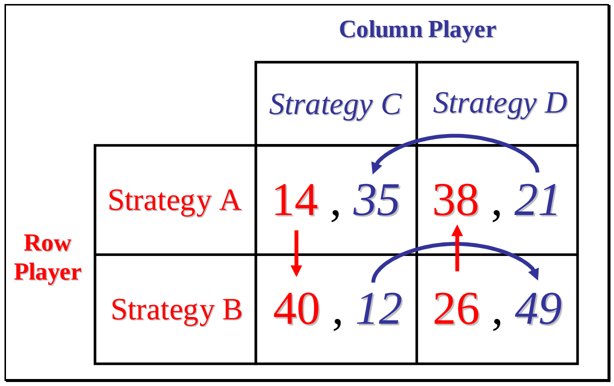

Figure 10. Hypothetical Payoff Matrix Requiring a Mixed-Strategy Solution

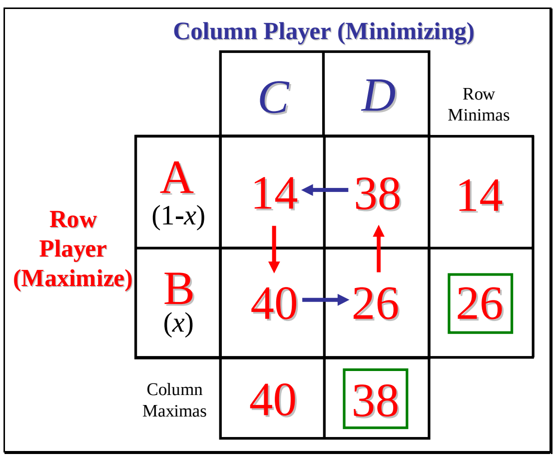

Figure 11. Row Player's Equivalently Zero-Sum Game

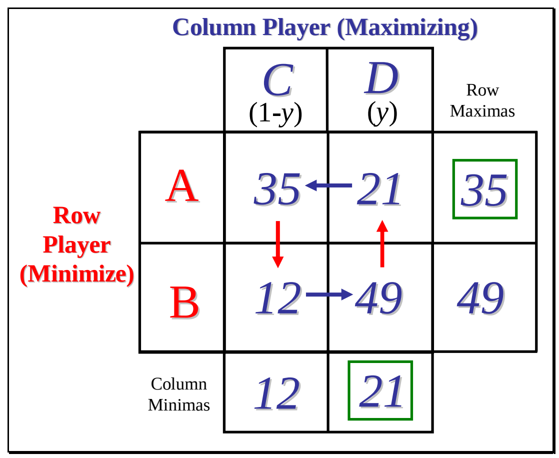

Figure 12. Column Player's Equivalently Zero-Sum Game

In the spirit of an equivalently zero-sum game where all outcomes are PO, if either player uses his equalizing strategy, he effectively removes the other player from the game, since that player cannot unilaterally improve upon his situation. The value of this game represents the minimum outcome that a player can guarantee himself if the other player turns hostile. As shown in figures 11 and 12, there are no saddlepoints in either of these equivalently zero-sum games. Had there been a saddlepoint in the row player's game, for example, that value would have represented the row player's value of the game and security level; regardless of what the column player does, the row player guarantees himself an outcome no less than this value. Just as before, in cases with no saddlepoint, players determine their mixed-strategy solutions using the concept of equalizing expectations explained in the section on mixed-strategy solutions for zero-sum games.

In the row player's game (figure 11), the row player is maximizing and the column player is minimizing, or attacking, the row player. Using the formula for EV, if pursuing pure strategies to minimize the row player's gains, the column player's EVs would be:

$$v \leq \text{EV (Strategy C)} = 14(1\text{-}x) + 40(x) = 14\text{+}26x$$

$$v \leq \text{EV (Strategy D)} = 38(1\text{-}x) + 26(x) = 38\text{-}12x$$

The row player can equalize the column player's expectations by setting the two EVs equal to each other, and then solving for *x*:

$$\text{EV (Strategy C)} = \text{EV (Strategy D)}$$

$$14\text{+}26x = 38\text{-}12x$$

$$24 = 38x$$

$$x = .632 \text{ or } 63.2\% \ (x = \text{optimal percentage for choosing Strategy B})$$

$$(1\text{-}x) = .368 \text{ or } 36.8\% \ ((1\text{-}x) = \text{optimal percentage for choosing Strategy A})$$

This analysis assumes that the column player is hostile, and is not concerned about his profit while he seeks to minimize the row player's profit. Regardless of the column player's strategy, if the row player follows his prudential mixed strategy of selecting Strategy A roughly thirty-six percent of the time, and Strategy B about sixty-three percent {.368 A, .632 B}, the row player is assured of earning, on average, an outcome of no less than the value of the row player's game. The row player determines his security level and value of the game (30.4) by substituting the value for x into either of the column player's pure-strategy EVs:

$$\text{EV (Strategy C)} = 14+26x \quad \text{or} \quad \text{EV (Strategy D)} = 38-12x$$

$$14+26(.632) \quad \text{or} \quad 38-12(.632)$$

$$30.4 \quad \text{or} \quad 30.4 = \text{the value of the game and row player's security level}$$

Unlike the zero-sum game's mixed-strategy solution, there is no need to determine a column player's prudential strategy for the row player's game because the column player will always choose the strategy that damages the row player the most. While the column player may be concerned with his profits in the row player's game, the column player must use the same process to determine his own prudential strategy when analyzing the column player's game (figure 12). When minimizing the column player's game, the row player's pure-strategy EVs would be:

$$v \leq \text{EV (Strategy A)} = 35(1\text{-}y) + 21(y) = 35\text{-}14y$$

$$v \leq \text{EV (Strategy B)} = 12(1\text{-}y) + 49(y) = 12\text{+}37y$$

Just as in the row player's game, the column player equalizes the expectations of the row player's two pure-strategy EVs in the column player's game by setting the two EVs equal to each other and solving for y. This analysis also assumes a hostile row player who is not concerned about his profit while seeking to minimize the column player's profit:

EV (Strategy A) = EV (Strategy B)
35-14y = 12+37y
23 = 51y
y = .451 or 45.1% (y = optimal percentage for choosing Strategy D)
(1-y) = .549 or 54.9% ((1-y) = optimal percentage for choosing Strategy C)

Regardless of the row player's strategy, if the column player follows his prudential mixed strategy of selecting Strategy C about forty-five percent of the time, and Strategy D roughly fifty-four percent {.451 C, .549 D}, the column player is assured of earning, on average, an outcome of no less than the value of the column player's game. The column player determines his security level and the value of his game (28.7) by substituting the value for *y* into either of the row player's pure-strategy EVs:

EV (Strategy A) = 35-14y or EV (Strategy B) = 12+37y
35-14(.451) or 12+37(.451)
28.7 or 28.7 = the value of the game and column player's security level

The solution of this game is the two values of the game (30.4 for the row player and 28.7 for the column player), the row player's prudential mixed strategy {.368 A, .632 B}, and the column player's prudential mixed strategy {.451 C, .549 D}. If both players used their respective prudential strategies, the outcome would be (30.4, *28.7*), but this result is not PO. Only through techniques of cooperation or arbitration would both players be able to improve their outcome and achieve a solution that is PO. Discussions on applying the concept of Nash arbitration to determine a PO Nash point in variable-sum mixed-strategy games will follow in chapter 4 if necessary.

Strategic Moves

The use of strategic moves, such as commitments, threats, and promises, offers solutions to escape situations where players do not choose strategies simultaneously or choose strategies without communication. Considering strategic moves in zero-sum games with no saddlepoint and consecutive moves, the player who moves last has a distinct advantage and benefits from knowing the other player's choice before moving himself. In variable-sum games there are instances when it is beneficial to make the first move.

If not possible for one player to move first in a game, communicating a commitment to a move could achieve the same effect. The difficulty arises in trying to make a commitment convincing to the other player, especially when the other player would like to commit and when conflicting commitments are mutually damaging. In cases where conflicting commitments are mutually damaging, one can make a commitment, and then sever communications, thereby forcing the other player to either give in or risk receiving a less preferred outcome (Straffin 1996, 85-86).

In situations where commitments would not affect the game, one may be able to apply an effective threat. A threat in the context of game theory must have the following properties: (1) "Player 1" agrees to take a certain action contingent on a previous action by "Player 2;" (2) Player 1's action will be harmful to Player 2; and (3) Player 1's action will also harm Player 1. Credibility is the crux of the successful use of threats, and is difficult to achieve since the obligation is to a self-harmful action (Straffin 1996, 86-88).

In instances where threats are not credible, a promise may be appropriate, and has the following properties: (1) Player 1 agrees to take a certain action contingent on a previous action by Player 2; (2) Player 1's action will be beneficial to Player 2; and (3) Player 1's action will harm Player 1. Once again, the issue for effectively applying this strategic move is credibility, especially convincing one's opponent of a commitment to take a self-harmful action. In cases where threats and promises are not sufficient, a combination of both a threat and a promise might be sufficient to change the outcome if they are both credible. In other instances, no combination of commitments, threats, or promises can change a game (Straffin 1996, 86-88).

CHAPTER 3

GAME THEORY APPLIED TO PERSONNEL RECOVERY

When considering game theory and its application to military PR operations, the question focuses on how game theory can assist military planners in conducting successful PR operations. Game theory's operational and strategic value with regard to PR overshadows any of its tactical limitations. Game theory cannot tell PR planners how to conduct recovery operations; rather, it can predict outcomes of all combinations of COAs to allow for selection of the most advantageous strategy.

Further analysis into strategic preferences and national interests reveals that, while U.S. goals and desires remain somewhat constant, the motivations of its potential adversaries can vary greatly. Furthermore, it is reasonable to assume that not every adversary of the U.S. will place the same value on capturing IP--the values assigned by transnational terrorists could be significantly different from the values assigned by a country with a first-rate military. With this in mind, given the U.S.'s two basic options of recovering or not recovering IP using traditional PR methods, it is necessary to categorize potential adversaries of the U.S. by a combination of their motivations and capabilities given two basic choices of capturing or not capturing IP.

Acknowledging that an adversary is a thinking opponent, choosing a strategy is often not a simple case of yes or no. In deciding not to capture IP, for example, an adversary might consider a wide range of possible calculations, including issues such as insufficient means to capture the IP; favoring chances to ambush RFs to inflict additional casualties and equipment losses; inadequate intelligence of the IP's location or disposition; higher priority missions elsewhere; fear of a decisive engagement with the U.S.; force preservation or survival; or a perceived probability of failure. When using game theory to analyze and compare different categories of adversaries, the rationale supporting players' preferences is less important than is the actual ranking of those preferences, since the ranking determines the matrix values.

Determining generic categories of potential adversaries at first seems an overly subjective process, but given adversaries are rational actors, in that they make choices they perceive to be the most beneficial to achieving some end, their strategic choices support their agendas, and their capabilities determine feasible COAs. When this end involves capturing IP, the consequences of doing so must fall below an adversary's perspective of an acceptable threshold of risk. There appear to be several motivational- and capabilities-based categories necessary to analyze potential PR scenarios.

After initially analyzing the various adversarial groups, it becomes quickly apparent that the two-person total-conflict (zero-sum) game has limited application to the multitude of PR scenarios. As previously discussed, for the zero-sum game to be applicable, the most preferred action by one player must also be the least preferred by the other. Therefore, the noncooperative circumstances PR planners and RFs face are better suited for partial-conflict analysis, which provides a more useful tool for planning PR.

PR Scenario 1: First-Rate Adversary

First, there is the worst-case scenario for PR, in which RFs face a first-rate adversary, such as China. Under such circumstances, there will be no guarantee, at least initially, that the U.S. will have either air superiority or freedom of maneuver. Adversaries faced with the decision of whether or not to capture IP in areas under their control would find few reasons not to do so, provided that doing so was tactically and operationally feasible. The propaganda value of a captured IP would be less of a deciding factor, because such asymmetric tactics would not be the primary focus of an enemy who has decided to fight the U.S. on the conventional battlefield. Without air superiority, traditional U.S. rotary- and fixed-wing RFs would require overwhelming aviation support packages to increase the probability of success to an acceptable level. Even then, given the low probability of success and the high probability of further losses, the risk to RFs would probably be such that recovery would be a feasible or acceptable option in only the rarest of cases. Figure 13 illustrates the ordinal preferences of both the U.S. and a first-rate adversary; the larger the number, the higher that player's preference for a given outcome between opposing COAs.

		United States	
		Recover	*No Recover*
Enemy	Capture	4 , *1*	2 , *2*
	No Capture	3 , *3*	1 , *4*

Figure 13. PR Payoff Matrix: First-Rate Adversary versus the U.S.

As shown in figure 13, when the enemy selects "Capture" and the U.S. selects "Recover," this is the best scenario for the adversary and the worst for the U.S. because of the high probability of more U.S. losses, and the lowest probability of recovery (4 , *1*).

Conversely, the best outcome for the U.S., and the least preferred for this adversary occurs when the adversary chooses “No Capture” and the U.S. chooses “No Recover” (1 , *4*). The enemy inflicts no further losses on RFs, and the U.S. gives the IP an opportunity for success through survival, evasion, and eventually self-recovery. Both players receive their next least preferred outcomes when the U.S. chooses No Recover and the adversary chooses Capture (2 , *2*). While the adversary will not have the opportunity to inflict further casualties on U.S. RFs, since the U.S. is not attempting a recovery, it is very likely that the adversary will capture the IP. Both players can obtain their next most preferred outcomes when the U.S. chooses Recover when the adversary chooses No Capture (3 , *3*). When this adversary selects No Capture, the IP has an easier time evading, and there is more planning time for RFs to develop and execute a plan that exploits a weakness in defense. For the adversary, there will be an opportunity to inflict further casualties on the RFs, as well as a higher expectation that calculated military inaction might still result in a capture by means of civilian assistance in locating and securing the IP.

<u>PR Scenario 2: Second-Rate Adversary</u>

The next type of enemy involves a second-rate adversary, or one with the ability to attack outside its borders and possessing second-generation weapons technology. Against such an adversary, though not guaranteed, the U.S. would likely be able to establish local air superiority or short-term air parity over a limited geographical area. Again, without possessing air superiority, traditional rotary- and fixed-wing RFs would require substantial aviation support packages to increase their probability of conducting a successful recovery. Only in situations where the U.S. could set the right conditions for a specific period would PR be a feasible option for U.S. RFs. The U.S. could expect an adversary in such a position to exploit the vulnerabilities of recovery aircraft, and opportunistically attempt to interdict RFs without risking the loss of critical assets needed to deny the U.S. air superiority. The propaganda value of a captured IP now begins to become more of a factor in deciding whether to attempt to capture the IP. Second-rate adversaries will employ asymmetric tactics to mitigate some of the differences in conventional capabilities. Figure 14 illustrates the ordinal preferences for both the U.S. and a second-rate adversary.

		United States	
		Recover	*No Recover*
Enemy	Capture	3 , *2*	4 , *1*
	No Capture	2 , *3*	1 , *4*

Figure 14. PR Payoff Matrix: Second-Rate Adversary versus the U.S.

The most and least preferred options for both players occur when the U.S. chooses No Recover. The least preferred scenario for the U.S. and the most preferred for an adversary occurs when the adversary selects Capture and the U.S. selects No Recovery (4 , *1*). The U.S.'s most preferred situation occurs when the adversary chooses No Capture because there is no possibility of RF interdiction, and IP have the best opportunity for success through survival, evasion, and eventually self-recovery (1 , *4*). The next most preferred option for the adversary, and the next least preferred for the U.S.

occurs when both players pursue the IP (3 , *2*). The enemy has the opportunity to inflict more losses on the RFs, and the U.S. has no guarantee of success given the enemy's capabilities. Finally, the next most preferred option for the U.S. and the next least preferred for the adversary occurs when the U.S. selects Recover and the adversary chooses No Capture (2 , *3*). Under this scenario, the U.S. has the best opportunity to set the conditions for a limited time or geographic area, and the enemy has less than an optimal chance at interdicting RFs since he is not dictating the terms of the engagement.

PR Scenario 3: Third-Rate Adversary with Poor Popular Support

The next scenario considers the third-rate state actor with poor popular support, where the state uses its military primarily as a means of population control and defense against foreign aggression. With weak control over its constituents and a conventional force incapable of sustained combat operations against the U.S.'s conventional dominance, this adversary would likely base his decision to capture IP based on force preservation. If it were realistic for the adversary to attempt to capture the IP with a high probability of success and with a reasonable assurance of force preservation, then the benefit of exploiting a hostage would outweigh the costs. Proximity to the IP is likely the key factor in the adversary's decision-making process, since forces must reach the location, capture the IP, and remove the IP from the area before RFs arrive. With weak popular support, there is little expectation of civilian assistance in capturing IP. A likely COA is for this type of adversary would be to capture IP and publicly threaten bodily harm if the U.S. did not meet his demands to withdraw U.S. forces.

Third-rate adversaries faced with imminent defeat will likely plan for a transition into an underground movement, whereby they can employ unconventional warfare and guerrilla tactics to leverage asymmetric advantages. Capturing IP gives a weaker adversary a bargaining tool when faced with the inevitable defeat of its military--propaganda targeting the U.S. center of gravity, or the American populace's will to fight. Figure 15 illustrates the ordinal preferences for both the U.S. and the third-rate adversary with poor popular support.

		United States	
		Recover	*No Recover*
Enemy	Capture	3 , *3*	4 , *1*
	No Capture	2 , *4*	1 , *2*

Figure 15. PR Payoff Matrix: Third-Rate Adversary (Poor Support) versus the U.S.

The most preferred scenario for the U.S. is the next least preferred for the enemy (2 , *4*). When the U.S. selects Recover and the enemy chooses to do nothing, the U.S.'s conventional superiority virtually ensures mission success, and the enemy appears to be powerless to foil his foe. The next most preferred choices for both players occur when both decide to secure the IP (3 , *3*). The U.S.'s military superiority will likely prevail, but third-rate adversaries still have the undeniable potential to hinder PR missions. The enemy will maintain some of his reputation by challenging the Americans, but this COA will only be viable if the enemy can complete the capture before RFs arrive. The most preferred scenario for the enemy, and the least preferred for the U.S. is when the U.S. does nothing while the enemy selects Capture (4 , *1*). The least preferred scenario for the enemy and the second least preferred for the U.S. occurs when neither player attempts to secure the IP (1 , *2*). With poor popular support, the enemy would not anticipate voluntary assistance from the locals, and the U.S. would show weakness by not dominating a much weaker military opponent.

PR Scenario 4: Third-Rate Adversary with Good Popular Support

In the case of the third-rate state actor with good support for its populace, there is only a slight variation from the third-rate state actor with poor support model depicted in figure 15. With a realistic expectation of at least moderate civilian support, there is a higher probability that local civilians will turn over IP to government officials. Due to this, there is a chance that the third-rate government can gain control of the IP without risking military forces. Support from civilians could manifest itself in two primary ways: the population could physically aid in the capture of the IP or it could provide varying degrees or combinations of active or passive aid in opposing RFs. This is more preferred than not attempting to capture the IP, given a certainty that U.S. RFs will deploy and likely succeed if there is no resistance. Figure 16 illustrates the ordinal preferences for both the U.S. and a third-rate adversary with good popular support in such a situation.

		United States	
		Recover	*No Recover*
Enemy	Capture	3 , *3*	4 , *1*
	No Capture	1 , *4*	2 , *2*

Figure 16. PR Payoff Matrix: Third-Rate Adversary (Good Support) versus the U.S.

The most preferred scenario for the U.S. is the least preferred for the enemy (4 , *1*). When the U.S. selects Recover and the enemy chooses to do nothing, the U.S.'s conventional superiority virtually ensures mission success, and the enemy appears to be powerless to protect himself. The next most preferred choice for both players occurs when both attempt to secure the IP (3 , *3*). The U.S.'s military superiority will likely prevail, but third-rate adversaries still have the undeniable potential to hinder PR missions. The enemy will maintain some of his reputation by challenging the Americans, but this COA will only be viable if the enemy can complete the capture before RFs arrive. The most preferred scenario for the enemy, and the least preferred for the U.S. occurs when the U.S. does nothing while the enemy selects Capture (1 , *4*). The second least preferred scenario for both players occurs when neither player attempts to secure the IP (2 , *2*). With good popular support, the enemy would have some expectation of civilian assistance from the locals, and the U.S. would show weakness because of the perceived inability or unwillingness to dominate a much weaker military opponent.

PR Scenario 5: Locally Focused Insurgent Group

Moving away from conventional, uniformed military adversaries, the U.S. must still contend with those nonstate players who could gain an advantage from capturing IP. The current situation in Operation Iraqi Freedom (OIF) offers examples of two such adversaries for consideration. This scenario focuses on the first example of the Iraqi insurgent, or freedom fighter, whose goal is local in nature. This type of insurgent uses asymmetric guerrilla-type tactics, and has the ultimate goal of assuming control over his government at the national (state) level or below.

Insurgency is a strategy adopted by groups too weak to attain their locally focused political objectives through conventional means or by a quick seizure of power. Characterized by protracted and asymmetric violence, ambiguity, the use of complex terrain, psychological warfare, and political mobilization, the locally focused insurgents employ tactics designed for self-protection and eventual alteration of the balance of power in their favor. Locally focused insurgents may attempt to seize power and replace the existing government (revolutionary insurgency), or they may have more limited aims, such as separation, autonomy, or alteration of a particular policy. They avoid battlespaces where they are weakest, typically the conventional military spectrum, and focus in areas where they can operate on footing that is to their advantage. Insurgents try to postpone decisive action, avoid defeat, sustain themselves, expand their support, and over time change the power balance in their favor. When pursuing strategies to weaken the national government by winning the support of the neutral or uncommitted, some refer to it as a national insurgency (Metz and Millen 2004, 2-3).

With U.S. intervention supporting Iraqi provisional, interim, and transitional governments, guerrillas in Iraq must combat two opponents to realize their goals. As long as the U.S. actively supports the transitioning Iraqi government, the insurgents have less of a chance at succeeding at overthrowing the target regime. The best strategy for an adversary faced with such circumstances is to attack the U.S.'s alleged center of gravity--the will of its people. In order to force the U.S. to abandon its support to the new regime, insurgents must appear strong while simultaneously attacking the U.S.'s legitimacy and credibility, and the perception that the U.S. is in control of the situation. Insurgents want IP for their information operations (IO) campaigns since they cannot afford decisive engagements with U.S. forces. The IO focus is much more important than setting an ambush in hopes of inflicting further casualties on RFs. Since the insurgents will only fight if in total control of the time and place of the engagement, capturing IP purely to finance the organization through extorting a ransom is yet another more preferred option than setting an ambush.

Money to finance future operations facilitates a long-term protracted struggle and is more beneficial than the short-term gains won by risking losses to ambush the militarily superior U.S. RFs. With at least some level of passive public support, and even minimal active support, there is a reasonable expectation that the local populace will give captured IP to the insurgents. This dynamic will vary according to the amount of control the regime exercises through its military and police forces in the area, and to what extent the insurgents have mistreated the local inhabitants. However, coercing public support to assist in their efforts to fight the U.S., including capturing IP, is preferred to risking insurgent lives without a high probability of success of capturing IP themselves--especially during hours of daylight. Figure 17 illustrates the ordinal preferences for both the U.S. and the locally focused insurgent adversary.

		United States	
		Recover	*No Recover*
Enemy	Capture	2 , *3*	4 , *1*
	No Capture	1 , *4*	3 , *2*

Figure 17. PR Payoff Matrix: Locally Focused Insurgents versus the U.S.

The most preferred choice for these insurgents is to capture IP with no U.S. interference (1 , *4*), thus showing that the insurgents are strong and the U.S. cannot protect itself or the country it is there to help. Conversely, the most preferred outcome for the U.S. and the least preferred for the insurgents occurs when the U.S. selects Recover and the insurgents do nothing (4 , *1*). The populace would consider the insurgent group as weak and incapable of providing protection to the citizens. The next least preferred scenario for the insurgents and the second most preferred for the U.S. occurs when both players attempt to secure the IP (2 , *3*). Insurgents would have an opportunity to gain a propaganda victory and inflict further casualties through engaging RFs, but would only attempt an ambush in the unlikely event that the insurgents had confidence in their ability to dictate favorable terms of engagement to ensure the preservation of forces and mission success. While insurgents typically operate dispersed to avoid detection, those rare occasions when they could mass sufficient forces to dominate an engagement from a position of advantage could be disastrous for RFs. The next least preferred scenario for the U.S. and the second most preferred for the insurgent occurs when both players decide not to secure the IP (3 , *2*). The insurgents have a higher expectation for local support in obtaining IP, and the U.S.'s inaction demonstrates a lack of strength and control--playing into the insurgents' IO efforts.

PR Scenario 6: Globally Focused Insurgent Group

Another challenge present in OIF is the presence of foreign fighters representing the transnational or global insurgency of al Qaeda. Clearly, al Qaeda is not a conventional force, nor do they aspire to overthrow the regime in Iraq for any reason other than the fact that it represents U.S. or Western influence in the Middle East. With no desire to eventually rule in Iraq, the motivation and goals of this type of adversary are very different from those of the local freedom fighter who wants to gain or regain control of his local sovereignty. The goal of this global insurgency is to use terrorism to compel the U.S. to remove its influence from the Middle-Eastern region, or arguably to promote a "clash of civilizations" between Muslim and non-Muslim religious groups.

Similar to the locally focused insurgent's strategies, this type of adversary adds a transnational, international, or globally focused agenda relying more heavily on guerrilla and terrorist tactics to compel foreign governments to take desired actions. Often referred to as "liberation" insurgencies, these insurgents attack groups viewed as outside occupiers by virtue of race, ethnicity, or culture. The goal of the global insurgents is to liberate the group they claim to represent from this alien occupation. What generally motivates these insurgents is not the lack of jobs, schools, or the right to vote, but rather resentment at the unwanted occupation, interference, influence, and rule by outsiders or those perceived as outsiders (Metz and Millen 2004, 2-4).

With less inherent or perceived legitimacy and credibility than locally focused insurgents, the global insurgent's best method of attacking the U.S. is through IO, and, to that end, capturing Americans is of critical importance. Capture dominates the strategy of No Capture, regardless of what the U.S. decides to do when faced with this enemy. With groups that welcome martyrdom in pursuit of their goals, the potential propaganda value of IP is worth the potential loss of even an entire cell--depending, to a certain extent, on the overall maturity of the network. This is not to say that an entire cell is expendable--the leaders, or core foreign-fighter planners, are more risk averse and usually only direct surrogates to conduct the actual operations, vis-à-vis disgruntled members of the former

Iraqi regime in the context of OIF. Moreover, since they are not members of the local populace, global insurgents are less trusting of the local civilians, especially when the U.S. offers monetary rewards for information--a very strong incentive in a culture marked by shifting alliances.

Under such operational constraints, the global insurgent is more apt to operate at night than during the day, but would likely risk exposure to capture IP. Ultimately, the global insurgent would exploit the IP for propaganda purposes, aimed at deteriorating coalition support and resolve, as well as the will of the American population. Once these insurgents have exploited the propaganda value of the IP, they may give the IP to any of the local insurgent groups to reinforce their mutually supportive relationship and to strengthen the bonds formed from having a common enemy. An alliance between local and global insurgent groups can increase the global insurgent's capabilities, resources, and appeal to a larger audience. Figure 18 illustrates the ordinal preferences for both the U.S. and the globally focused insurgent adversary.

		United States	
		Recover	*No Recover*
Enemy	Capture	3 , *3*	4 , *1*
	No Capture	1 , *4*	2 , *2*

Figure 18. PR Payoff Matrix: Globally Focused Insurgent Group versus the U.S.

The most preferred outcome for the global insurgent and the least preferred for the U.S. is when insurgents choose Capture with no U.S. interference (4 , *1*), thus showing that the insurgents are strong and the U.S. cannot protect itself or the country it is there to assist. Conversely, the most preferred outcome for the U.S. and the least preferred for the global insurgents occurs when the U.S. selects Recover and the insurgents do nothing (1 , *4*). The insurgents would lose an opportunity to capitalize on the propaganda value of a "David and Goliath" success story vital for both local and global recruitment, and would likely suffer negative propaganda if the group consistently demonstrated an inability to counter the U.S.

The next most preferred scenario for both players occurs when both attempt to secure the IP (3 , *3*). Global insurgents would have an opportunity to gain a propaganda victory and inflict further casualties through engaging RFs, and would be more likely to attempt a hasty ambush than would be locally focused insurgents--regardless of the ability to dictate favorable terms of engagement or expectations of success. However, the probability of global insurgents dominating an engagement from a position of advantage or inflicting more casualties on the RF would be lower than that of the local insurgent. The next least preferred scenario for both players occurs when both decide not to secure the IP (2 , *2*). The global insurgents would have lower expectations for local support in obtaining the IP, but the U.S.'s inaction would demonstrate a lack of strength and control, and would play into the global insurgents' IO efforts.

PR Scenario 7: Criminal Element or Organization

The final category of possible adversaries for the U.S. is the criminal threat, or those individuals or groups motivated not by political goals, but rather by personal profit.

This adversary, more often than not, is present throughout the operational continuum--from peacekeeping and other humanitarian operations to high-intensity conventional wars. In recent years, kidnapping for ransom has become a common trend throughout the world. As a relatively easy method of collecting revenues to finance future operations, terrorists, insurgents, and criminals alike have benefited from such activity. In order to differentiate this category of adversary from those previously discussed, it is essential to emphasize the unique goal of most criminal organizations. The criminal threat generally has no political motive--only a desire to increase personal wealth and status. Figure 19 illustrates the ordinal preferences for both the U.S. and a generic criminal entity when faced with the prospects of capturing IP.

		United States	
		Recover	*No Recover*
Enemy	Capture	1 , *3*	4 , *1*
	No Capture	3 , *4*	2 , *2*

Figure 19. PR Payoff Matrix: Criminal Element versus the U.S.

Under optimal conditions, a criminal element would most likely desire to secure the IP and attempt to collect ransom directly from the nation from which the IP came. If not possible to negotiate with that nation, or if too risky a venture, a criminal element would simply pass IP to the highest bidders or to the group with the most to offer the criminals. However, criminals will generally be unwilling to engage U.S. forces directly in order to capture IP, so they will only pursue such a venture if the opportunity presents itself in such a manner as to be virtually free of risk. Likewise, the criminal element does not desire to engage the local military, police forces, or insurgent groups in order to capture IP. Competition from groups that can potentially threaten the criminal groups' survival is bad for the status quo.

The most preferred choice for criminal entities is to capture IP quickly without U.S. interference (4 , *1*), providing there is also no threat from competing insurgent, police, or local military forces. The most preferred choice for the U.S. and next most preferred for the criminals occurs when the U.S. selects Recover and the criminals do nothing (3 , *4*). The criminals would maintain the status quo and no other competitors would gain in status; however, the criminals would have no chance to gain in this situation. The next least preferred scenario for both players occurs when neither decides to secure the IP (2 , *2*). Other groups would now have the opportunity to gain from exploiting the IP, whereas the criminal group would have no occasion to gain anything. IP would still have the opportunity for self-recovery through survival and evasion, and their odds of success would increase with environments that are more permissive. The next most preferred scenario for the U.S. and the least preferred for the criminal occurs when both players decide to secure the IP (1 , *3*). This scenario is the worst for criminals because the criminal would want nothing more than to avoid direct confrontation with the U.S., since such a confrontation would undoubtedly threaten the organization's existence.

Cuban Missile Crisis Revisited: Determining Strategy Preferences

Returning to the Cuban missile crisis, one can now examine how the above discussion relates to the vignette. The immediate goal of the U.S. was to remove the nuclear missiles from Cuba, given two basic strategies of "Blockade" and "Strike." The two choices for the Soviets were "Depart" and "Defend." This situation represents the game commonly known as chicken, a two-person variable-sum game where each player chooses between swerving to avoid a crash or not swerving and risking a collision. If only one player swerves, that player loses the game. Neither player has a dominant strategy, yet there exists a compromise outcome when both players swerve and a disaster outcome when both players refuse to swerve. Figure 20 illustrates the ordinal preferences for both the U.S. and the Soviets at the beginning of the Cuban missile crisis.

		USSR	
		Depart	*Defend*
U.S.	Blockade	3 , *3*	2 , *4*
	Strike	4 , *2*	1 , *1*

Figure 20. Payoff Matrix: Cuban Missile Crisis (Ordinal Values)

Since there would be little chance of an immediate response from dismantled weapons, the most preferred choice for the U.S. and the next least preferred strategy for the Soviets would have been for the U.S. to launch a surgical air strike to destroy the missiles departing Cuba (4 , *2*), perhaps followed by an invasion of the island. If confirmed that the U.S. knowingly struck (not swerving) during the Soviet's withdrawal process (swerving), such a dishonorable act would not have played well in the court of public opinion, regardless of the U.S. win. The most preferred choice for the Soviets and the next least preferred strategy for the U.S. would have been for the Soviets to maintain the status quo (not swerving) with Kennedy relying only on a naval blockade (swerve) to prevent further missile shipments (2 , *4*). While allowing Kennedy time to plan stronger actions to induce the Soviets to withdraw all of their missiles in Cuba, an unyielding Soviet commitment to defend Cuba from an American invasion so close to the U.S. would have been a slap in the face, and a clear Soviet victory (Brams 2001).

The mutually least preferred outcome of a nuclear war (1 , *1*) would have involved a U.S. air strike (no swerve) to destroy the missiles that the Soviets refused to remove from the island (no swerve). While destroying missiles representing an imminent threat was arguably defensible by international standards, and even though the U.S. Air Force estimated it had a ninety percent chance of eliminating all of the missiles in Cuba, neither country wanted the responsibility of starting a thermonuclear war. The mutually next most preferred outcome of compromise (3 , *3*) would have involved the less invasive action of the U.S. blockade (swerve) and a Soviet withdrawal of all missiles from Cuba (swerve). Both sides would avoid a nuclear showdown by conceding their most preferred strategies and outcomes. The U.S. would have achieved its immediate goal of removing all missiles from Cuba, and through several smaller U.S. concessions, the Soviets would have bolstered the security of fellow Communists in Cuba, who were concerned about the next Bay of Pigs, as well as those bothered by Turkey-based U.S. missiles so close to the Soviet Union (Brams 2001).

CHAPTER 4

ANALYSIS

Using the models derived in chapter 3, and applying the principles of game theory discussed in chapter 2, one can evaluate each of the seven PR scenarios to determine likely outcomes in noncooperative situations. As a point of departure, the author should remind the reader that every two-person game has no less than one point of equilibrium in either pure or mixed strategies, as John Nash proved in 1950 (Straffin 1996, 66). Applying this premise to each of the seven variable-sum games from this thesis, the following analyses will first apply the minimax theorem to determine conservative, worst-case strategies. The next step will be to determine if these maximin strategies provide a stable outcome in pure strategy (Nash equilibrium), by ascertaining the players' security levels, status quo (SQ) point, and dominant strategies. If a unique equilibrium does exist, one can then evaluate the point to determine if it is PO. If no Nash equilibrium exists, neither player would want to play a single strategy with certainty, for the other player could take advantage of such a choice. After assigning cardinal values, one can then recalculate both players' security levels and determine the SQ point in order to ascertain the game's prudential or mixed-strategy equilibrium solution.

Analysis of PR Scenario 1: First-Rate Adversary

Applying the minimax theorem to the first game discussed in chapter 3, graphically portrayed in figure 13, results in the maximin analyses shown in figures 21 and 22. By each player determining his own corresponding row or column minimum values, each player can determine the better outcome from his worst possible outcomes--this is the worst that can happen. Following the maximin strategy of No Recover shows that the U.S. can do no worse than 2 (see the green box in figure 21), but if following a strategy of Recover, the U.S. could receive its worst possible outcome of 1. Likewise, by following a maximin strategy of Capture, the enemy could guarantee himself an outcome of no worse than 2 (see the green box in figure 22), whereas he would risk an outcome of 1 by following his strategy of No Capture. The unique value of the game, as well as both players' security levels, is 2.

		U.S.	
		Recover	*No Recover*
Enemy	Capture	*1*	*2*
	No Capture	*3*	*4*
	Column Minimum	*1*	$\boxed{2}$

Figure 21. U.S. Maximin Strategy Selection of No Recover

		U.S.		
		Recover	*No Recover*	Row Minimum
Enemy	Capture	4	2	$\boxed{2}$
	No Capture	3	1	1

Figure 22. First-Rate Adversary Maximin Strategy Selection of Capture

When combined, both players' corresponding maximin strategies of No Recover and Capture, intersect at the payoff strategy space of (2 , *2*). As is shown in figure 23, following maximin strategies offers a highly stable outcome. It is highly stable in this case, because when playing their maximin strategies, both players are also following their dominant strategies (graphically identifiable when all of a player's arrows point in the same direction). In all cases, it is better for this enemy to follow his strategy of Capture, since a payoff of 4 is better than 3 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 2 is better than 1 (if the U.S. decided to pursue its strategy of No Recover). Likewise, against this enemy, it is always better for the U.S. to follow its strategy of No Recover, since a payoff of 2 is better than 1 (if the enemy decided to pursue his strategy of Capture), and a payoff of 4 is better than 3 (if the enemy decided to pursue his strategy of No Capture). The pure-strategy Nash equilibrium of (2 , *2*) is the only payoff strategy space where all arrows point in, no arrows point out, and is represented by placing a circle around the payoff.

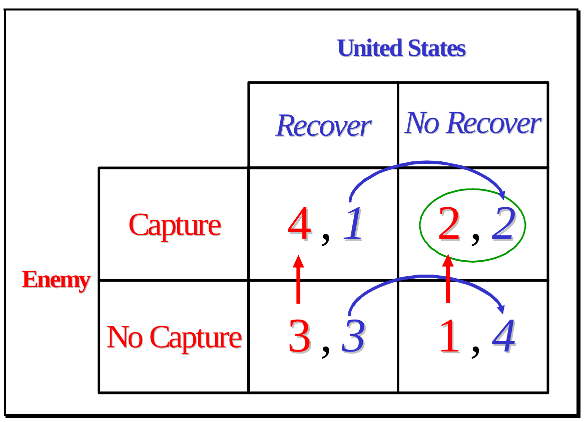

Figure 23. Analysis of PR Payoff Matrix: First-Rate Adversary versus the U.S.

Since there is a unique Nash equilibrium for this game, one must evaluate the solution to determine if it is PO. By plotting the points recorded in figure 23 onto a two-dimensional coordinate plane, one can further analyze the area bounded by the four points in the payoff matrix, or the game's feasible region of solutions. The solid area shown in figure 24 contains the game's entire solution set; there are no solutions outside of this highlighted area. Those points equal to or greater than both players' security levels dictate the reduced feasible region of solutions, given that noncooperative players can guarantee to do no worse than the value of their security levels playing conservatively. Figure 25 shows the reduction of the feasible region by graphing each player's security level of 2, and eliminating all possible solutions with values less than 2 (hashed area). The circled point represents the Nash equilibrium (2 , *2*), corresponding to strategy selections of Capture and No Recover.

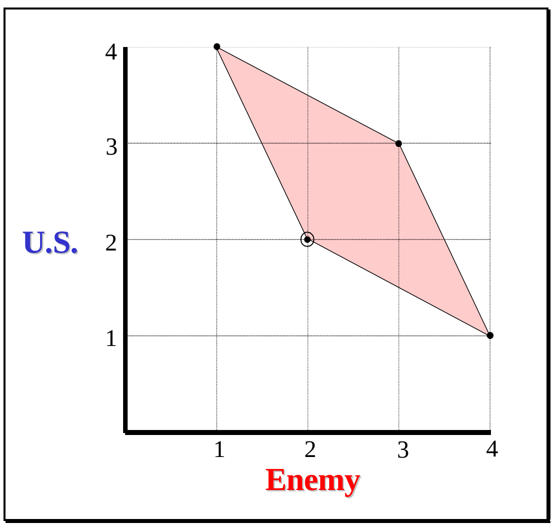

Figure 24. Feasible Region of Solutions (First-Rate Adversary versus the U.S.)

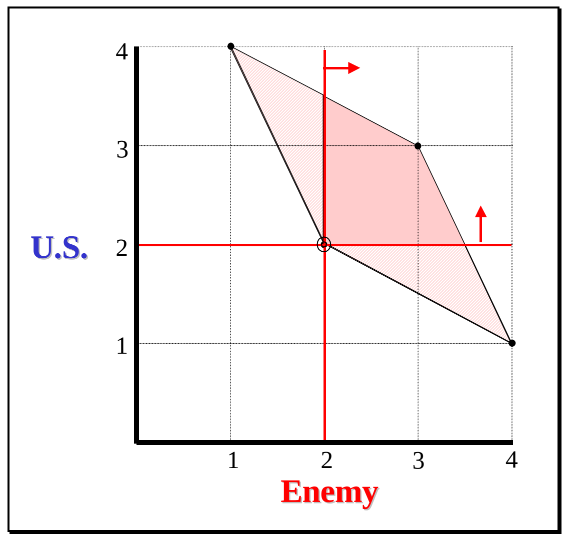

Figure 25. Reduced Feasible Region (First-Rate Adversary versus the U.S.)

In this instance, the unique Nash equilibrium is not PO. As figure 25 portrays, following strategy selections of No Capture and Recover (3 , *3*) affords both players higher payoffs than the equilibrium point, and lies within the reduced feasible region of possible solutions. The strategy choices of Capture and No Recover, while a Nash equilibrium (2 , *2*), is non-Pareto optimal. This situation at hand is the prisoner's dilemma--when each player strives to maximize his own payoffs independently, the result is worse than the better outcome of (3 , *3*), a difficult solution to attain when playing the game noncooperatively. If either player deviates from his dominant strategy, the payoff to player who moves to either (4 , *1*) or (1 , *4*) reduces his payoff to 1 while awarding his opponent their highest payoff of 4. There is no benefit to departing (2 , *2*) because the player who moves loses one unit of payoff, punishes himself with his worst payoff of 1, and awards two units of payoff to his opponent. Assuming the other player would not deviate from his dominant strategy, this situation deters both players from moving away from strategies not associated with the Nash equilibrium.

Even if both players could agree in advance to pursue the mutually beneficial outcome of (3 , *3*), corresponding to No Capture and Recover, the outcome is still unstable. If either player unilaterally reneges on the agreement and secretly executes his dominant strategy, he will benefit and obtain his most preferred payoff of 4. Accordingly, were play at (3 , *3*), each player would be strongly tempted to go back on his word and pursue his dominant strategy. In the unlikely case that the players could reach an agreement in advance, especially if they had little confidence in the trustworthiness of their opponents, they would have every justification to try to protect themselves from opponents reneging on the agreement by reneging on the agreement themselves.

Analysis of PR Scenario 2: Second-Rate Adversary

Applying the minimax theorem to the second game from chapter 3 (see figure 14) results in the maximin analyses shown in figures 26 and 27. Following its maximin strategy of Recover, figure 26 shows that the U.S. can do no worse than 2, but if following a strategy of No Recover, the U.S. could receive its worst possible outcome of 1. Likewise, figure 27 shows that by following a maximin strategy of Capture, the enemy guarantees himself an outcome of at least 3, while risking an outcome of 1 when following his strategy of No Capture. The value of the game and security levels are 2 for the U.S. and 3 for the enemy.

		U.S.	
		Recover	*No Recover*
Enemy	Capture	*2*	*1*
	No Capture	*3*	*4*
	Column Minimum	$\boxed{2}$	*1*

Figure 26. U.S. Maximin Strategy Selection of Recover

		U.S.		
		Recover	*No Recover*	Row Minimum
Enemy	Capture	3	4	$\boxed{3}$
	No Capture	2	1	1

Figure 27. Second-Rate Adversary Maximin Strategy Selection of Capture

When combined, both players' corresponding maximin strategies of Recover and Capture intersect at the payoff strategy space (3 , *2*). As shown in figure 28, following maximin strategies in scenario 2 results in a moderately stable outcome. The outcome is only moderately stable in this case because when playing their maximin strategies, only the enemy has a dominant strategy to pursue; the U.S. has no dominant strategy. In all cases, it is better for this enemy to follow his strategy of Capture, since a payoff of 3 is better than 2 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 4 is better than 1 (if the U.S. decided to pursue its strategy of No Recover).

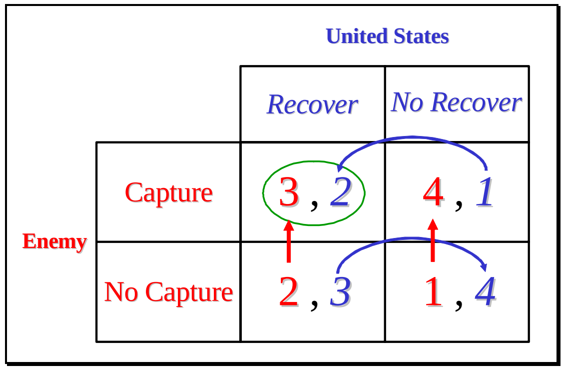

Figure 28. Analysis of PR Payoff Matrix: Second-Rate Adversary versus the U.S.

Against this enemy, the U.S.'s best strategy depends on what strategy it thinks the enemy will follow. If the U.S. determines that the enemy will follow his strategy of Capture, the U.S. would do better by following its strategy of Recover, since a payoff of 2 is better than 1. If the U.S. determines that the enemy will follow his strategy of No Capture, the U.S. would do better by following its strategy of No Recover, since a payoff of 4 is better than 3. Since the U.S. can determine that the enemy has a dominant strategy, and knows that a rational actor would follow his dominant strategy of Capture to secure either of his two highest payoffs of 3 or 4, the U.S. has to consider only those outcomes associated with the adversary's dominant strategy. When the enemy follows his strategy of Capture, the U.S. will secure a higher payoff by following its strategy of Recover. The pure-strategy Nash equilibrium for this game is (3 , *2*).

There is a unique Nash equilibrium for this game, and one must evaluate the solution to determine if it is PO by analyzing the game's entire solution set. The straight line of negative slope shown in figures 29 and 30 represents the feasible region of solutions, all of which are on this line. The circled point represents the Nash equilibrium. In this unique game, the sum of the payoffs in each of the payoff strategy spaces is a value of 5, so the game is equivalently zero sum; neither side can gain without the other side giving something up.

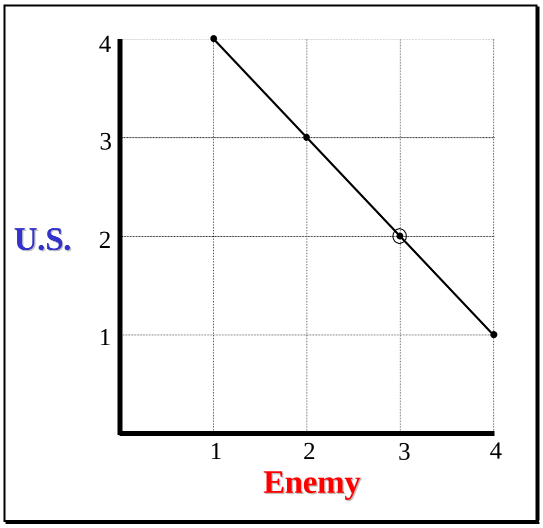

Figure 29. Feasible Region of Solutions (Second-Rate Adversary versus the U.S.)

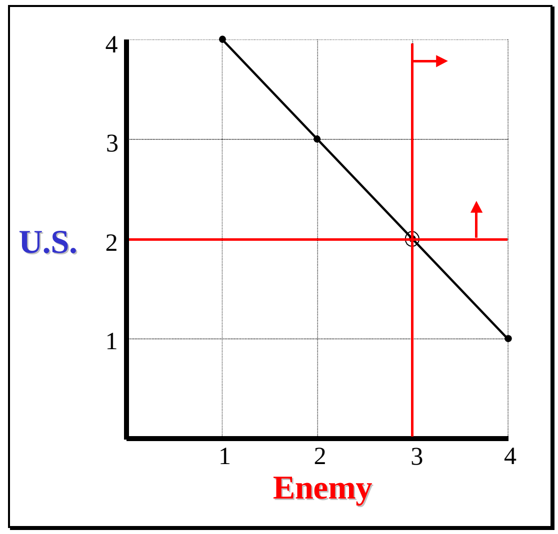

Figure 30. Feasible Region and Security Levels (Second-Rate Adversary versus U.S.)

By definition, every point along the line of negative slope is PO, including the equilibrium point. No other outcome offers both players higher payoffs, or gives one player the same payoff and the other player a higher payoff. While the U.S. would clearly prefer to secure its higher payoffs of 3 or 4, this is unattainable playing the game noncooperatively. If the U.S. were to change its strategy of Recover (3 , *2*) to No Recover, the resulting payoff of (4 , *1*) would increase the enemy's payoff by one, and reduce its own payoff by one. If the enemy were to change its strategy from Capture (3 , *2*) to No Capture, the resulting payoff of (2 , *3*) would increase the U.S.'s payoff by one, and reduce the enemy's payoff by one. There is no benefit to departing from the equilibrium point, because he who moves loses one unit of payoff and gives his opponent one additional unit of payoff.

<u>Analysis of PR Scenario 3: Third-Rate Adversary with Poor Popular Support</u>

Applying the minimax theorem to the third game from chapter 3 (see figure 15) results in the maximin analyses shown in figures 31 and 32. Following its maximin strategy of Recover, figure 31 shows the U.S. could guarantee itself no less than 3 following a strategy of Recover, but would risk receiving its least preferred outcome of 1 following a strategy of No Recover. Likewise, figure 32 shows that when following a maximin strategy of Capture, the enemy could guarantee himself an outcome of no less than 3, and would risk an outcome of 1 when following his strategy of No Capture. For each player in this scenario, the value of the game and security levels are all 3. When combined, both players' maximin strategies corresponding to Capture and Recover intersect at the payoff strategy space (3 , *3*).

		U.S.	
		Recover	*No Recover*
Enemy	Capture	*3*	*1*
	No Capture	*4*	*2*
	Column Minimum	$\boxed{3}$	*1*

Figure 31. U.S. Maximin Strategy Selection of Recover

		U.S.		
		Recover	*No Recover*	Row Minimum
Enemy	Capture	3	4	$\boxed{3}$
	No Capture	2	1	1

Figure 32. Third-Rate Adversary (Poor Support) Maximin Strategy of Capture

As is shown in figure 33, following maximin strategies in this scenario results in a highly stable outcome. It is highly stable because both players are following dominant strategies. In all cases, it is better for this enemy to follow the strategy of Capture, since a payoff of 3 is better than 2 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 4 is better than 1 (if the U.S. decided to pursue its strategy of No Recover). Likewise, against this enemy, it is always better for the U.S. to follow its strategy of Recover, since a payoff of 3 is better than 1 (if the enemy decided to pursue his strategy of Capture), and a payoff of 4 is better than 2 (if the enemy decided to pursue his strategy of No Capture). The pure-strategy Nash equilibrium associated with this game is (3 , *3*).

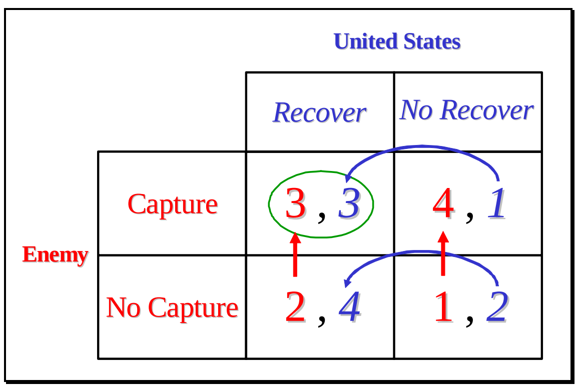

Figure 33. Analysis of PR Payoff Matrix: Third-Rate Adversary (Poor Support) versus the U.S.

Since this game has a unique Nash equilibrium, one must evaluate the solution to determine if it is PO by analyzing the feasible region of solutions shown in figure 34. Figure 35 shows a reduction of the feasible region by eliminating all solutions with a value less than 3, or those solutions left of and below lines representing both players' security levels. In this instance, the unique Nash equilibrium point is PO. As figure 35 clearly shows, there is no other outcome that gives both players higher payoffs, or gives one player the same payoff and the other player a higher payoff than the point (3 , *3*).

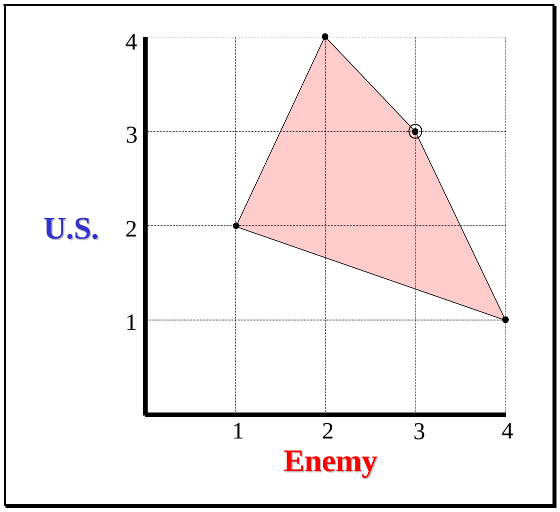

Figure 34. Feasible Region of Solutions (Third-Rate Adversary (Poor Support) versus the U.S.)

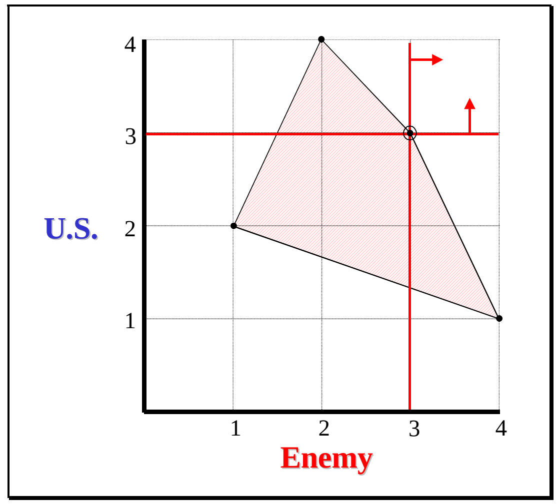

Figure 35. Reduced Feasible Region (Third-Rate Adversary (Poor Support) versus the U.S.)

While the U.S. would desire to increase its payoff to 4, this is unattainable when playing the game noncooperatively. If the U.S. were to change its strategy from Recover (3 , *3*) to No Recover, the resulting payoff of (4 , *1*) would raise the enemy's payoff by one, and reduce its own payoff by two. If the enemy were to change his strategy from Capture (3 , *3*) to No Capture, the resulting payoff of (2 , *4*) would raise the U.S.'s payoff by one and lower his own payoff by one. There are no benefits to departing from the equilibrium point, because the player who moves loses up to two units of payoff and gives his opponent one additional unit of payoff. Assuming the other player would not deviate from his dominant strategy, this situation deters both players from pursuing strategies not associated with the Nash equilibrium.

Analysis of PR Scenario 4: Third-Rate Adversary with Good Popular Support

Applying the minimax theorem to the fourth game from chapter 3 (see figure 16) results in the maximin analyses shown in figures 36 and 37. As shown in figure 36, when following its maximin strategy of Recover, the U.S. could do no worse than 3, but could receive its worst possible outcome of 1 if following a strategy of No Recover. Likewise, figure 37 shows that when following a maximin strategy of Capture, the enemy could guarantee himself an outcome of at least 3, but would risk an outcome of 1 following a strategy of No Capture. The value of the game and the security levels for both players are all 3. When combined, both players' maximin strategies corresponding to Capture and Recover intersect at the payoff strategy space (3 , *3*).

Enemy \ U.S.	*Recover*	*No Recover*
Capture	*3*	*1*
No Capture	*4*	*2*
Column Minimum	$\boxed{3}$	*1*

Figure 36. U.S. Maximin Strategy Selection of Recover

Enemy \ U.S.	*Recover*	*No Recover*	Row Minimum
Capture	3	4	$\boxed{3}$
No Capture	1	2	1

Figure 37. Third-Rate Adversary (Good Support) Maximin Strategy of Capture

As shown in figure 38, following maximin strategies in this scenario results in a highly stable outcome. Again, it is highly stable because both players are following dominant strategies. In all cases, it is better for this enemy to follow his strategy of Capture, since a payoff of 3 is better than 1 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 4 is better than 2 (if the U.S. decided to pursue its strategy of No Recover). Likewise, against this enemy it is always better for the U.S. to follow its strategy of Recover, since a payoff of 3 is better than 1 (if the enemy decided to pursue his strategy of Capture), and a payoff of 4 is better than 2 (if the enemy decided to pursue his strategy of No Capture). This game's pure-strategy Nash equilibrium is (3 , *3*).

		United States	
		Recover	*No Recover*
Enemy	Capture	3 , *3*	4 , *1*
	No Capture	1 , *4*	2 , *2*

Figure 38. Analysis of PR Payoff Matrix: Third-Rate Adversary (Good Support) versus the U.S.

Since this game does have a unique Nash equilibrium, one must evaluate the feasible region in figure 39 to determine if (3 , *3*) is PO. Figure 40 shows the reduced feasible region after graphing each player's security level of 3, and eliminating all solutions with a value less than 3, or all solutions left of and below lines representing both players' security levels. In this instance, the Nash equilibrium is PO. As figure 40 shows, there is no other outcome that gives both players higher payoffs or gives one player the same payoff and the other player a higher payoff when compared to (3 , *3*).

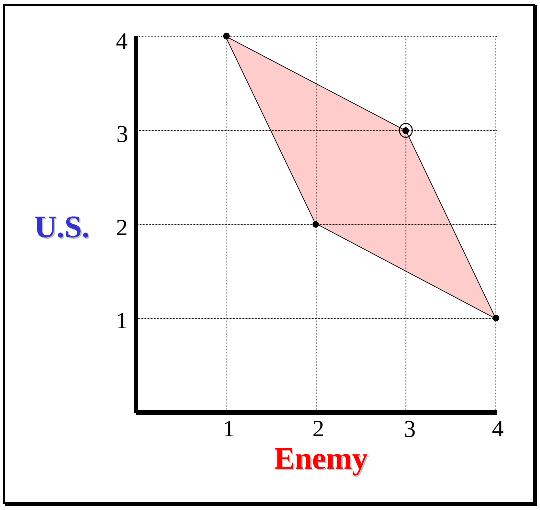

Figure 39. Feasible Region of Solutions (Third-Rate Adversary (Good Support) versus the U.S.)

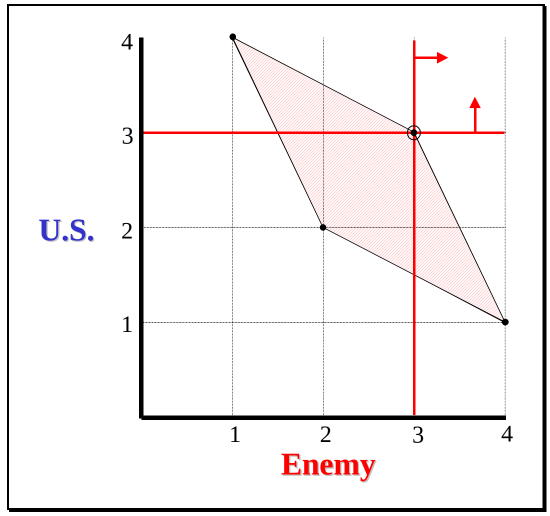

Figure 40. Reduced Feasible Region (Third-Rate Adversary (Good Support) versus the U.S.)

While the U.S. would prefer to obtain its highest payoff of 4, when playing the game noncooperatively this outcome is not reasonable. Ultimately, if either player were to change his strategy of either Capture or Recover (3 , *3*), the payoff to the player moving to either (4 , *1*) or (1 , *4*) drops from 3 to 1. There are no benefits to departing from (3 , *3*) because the player who chooses not to secure the IP loses two units of payoff, punishes himself with his worst payoff of 1, and gives one unit of additional payoff to his opponent. Assuming the other player would not deviate from his dominant strategy, this situation deters both players from selecting anything other than dominant strategies.

<u>Analysis of PR Scenario 5: Locally Focused Insurgent Group</u>

Applying the minimax theorem to the fifth game from chapter 3 (see figure 17) results in the maximin analyses shown in figures 41 and 42. Following its maximin strategy of Recover, figure 41 shows the U.S. could do no worse than 3, but if following its strategy of No Recover, it could receive its least preferred outcome of 1. Likewise, figure 42 shows that when following his maximin strategy of Capture, the enemy could guarantee himself an outcome of at least 2, but would risk an outcome of 1 if following a strategy of No Capture. The value of the game and security level is 3 for the U.S. and 2 for the enemy. When combined, the players' maximin strategies corresponding to strategies of Capture and Recover intersect at the payoff strategy space (2 , *3*).

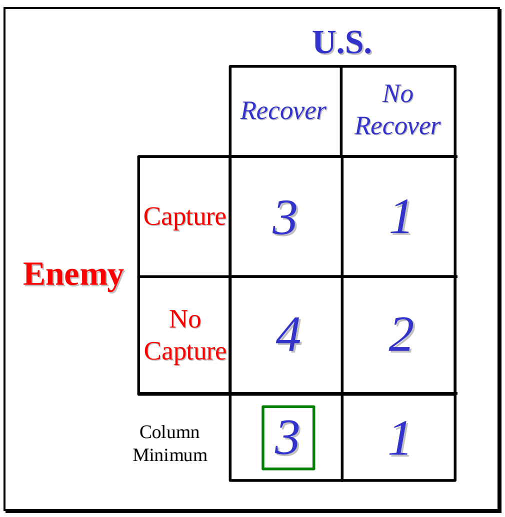

Figure 41. U.S. Maximin Strategy Selection of Recover

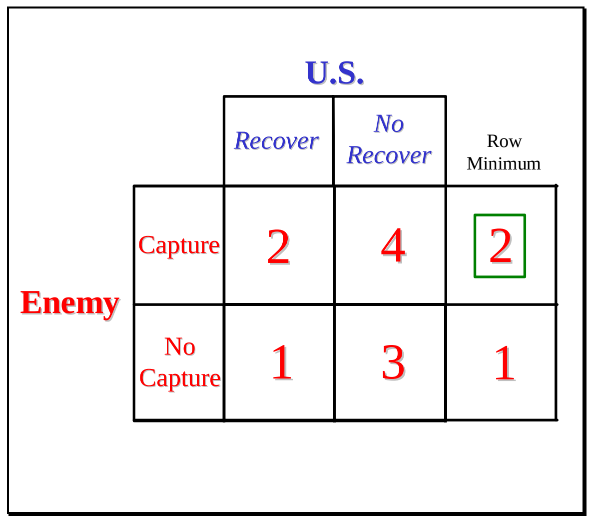

Figure 42. Locally Focused Insurgent Maximin Strategy Selection of Capture

As shown in figure 43, following maximin strategies in this example results in a highly stable outcome. The outcome is highly stable, because when playing their maximin strategies, both players are also following dominant strategies. In all cases, it is better for the locally focused insurgent to follow his strategy of Capture, since a payoff of 2 is better than 1 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 4 is better than 3 (if the U.S. decided to pursue its strategy of No Recover). Likewise, against this type of adversary, it is always better for the U.S. to follow its strategy of No

Recover, since a payoff of 3 is better than 1 (if the enemy decided to pursue his strategy of Capture), and a payoff of 4 is better than 2 (if the enemy decided to pursue his strategy of No Capture). The pure-strategy Nash equilibrium is (2 , *3*).

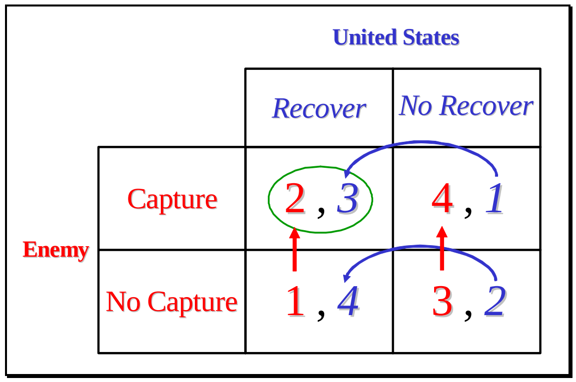

Figure 43. Analysis of PR Payoff Matrix: Locally Focused Insurgent versus the U.S.

Since this game has a unique Nash equilibrium, one must again evaluate the solution to determine if it is PO. As in PR scenario 2, the straight line of negative slope shown in figures 44 and 45 represents the game's feasible region of solutions. The circled point is the Nash equilibrium. The sum of the payoffs in each of the payoff strategy spaces is a constant value of 5, so PR scenario 5 is another game equivalently zero sum; neither side can gain without the other side giving something up. By definition, every point along the line, including the equilibrium point, is PO. There is no other outcome giving both players higher payoffs or giving one player the same payoff and the other player a higher payoff.

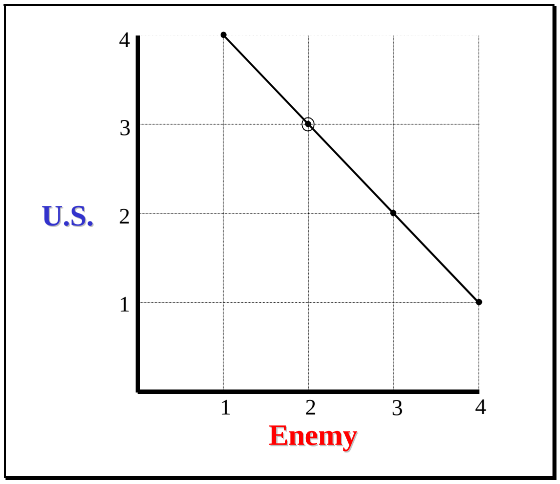

Figure 44. Feasible Region of Solutions (Locally Focused Insurgent versus the U.S.)

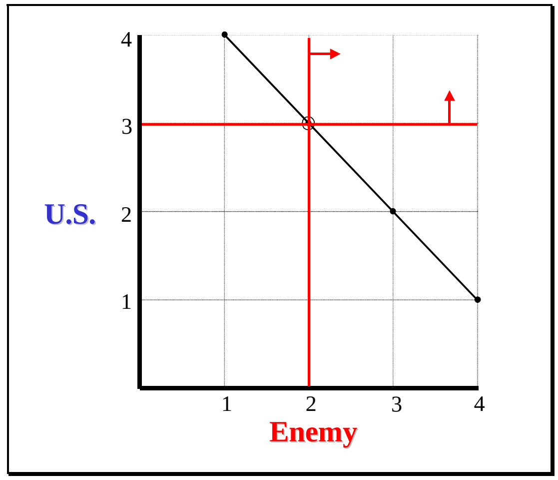

Figure 45. Feasible Region and Security Levels (Locally Focused Insurgent versus the U.S.)

While the U.S. would clearly prefer to secure its highest payoff of 4, this is unattainable playing the game noncooperatively. If the U.S. were to change its strategy from Recover (2 , *3*) to No Recover, the resulting payoff of (4 , *1*) would raise the enemy's payoff by two and reduce its own payoff by two. If the enemy were to change his strategy from Capture (2 , *3*) to No Capture, the resulting payoff of (1 , *4*) would raise the U.S.'s payoff by one and lower his own payoff by one. There are no benefits to departing from the equilibrium point, because the player who moves will lose up to two units of payoff and will reward his opponent with up to two additional units of payoff.

<u>Analysis of PR Scenario 6: Globally Focused Insurgent Group</u>

Applying the minimax theorem to the sixth game from chapter 3 (see figure 18) results in the maximin analyses shown in figures 46 and 47. Following its maximin strategy of Recover, figure 46 shows that the U.S. could do no worse than 3, but following a strategy of No Recover it could receive its least preferred outcome of 1.

Likewise, figure 46 shows that when following a maximin strategy of Capture, the enemy could guarantee himself a payoff of at least 3, but would risk an outcome of 1 following his strategy of No Capture. The value of the game and both players' security levels are 3.

		U.S. Recover	U.S. No Recover
Enemy	Capture	*3*	*1*
	No Capture	*4*	*2*
	Column Minimum	$\boxed{3}$	*1*

Figure 46. U.S. Maximin Strategy Selection of Recover

		U.S. Recover	U.S. No Recover	Row Minimum
Enemy	Capture	3	4	$\boxed{3}$
	No Capture	1	2	1

Figure 47. Globally Focused Insurgent Maximin Strategy Selection of Capture

When combined, both players' maximin strategies corresponding to Capture and Recover intersect at the payoff strategy space (3 , *3*). As revealed in figure 48, following maximin strategies in this scenario results in a highly stable outcome. Again, it is highly stable because both players are also following their dominant strategies. In all cases, it is better for the global insurgent to follow his strategy of Capture, since a payoff of 3 is better than 1 (if the U.S. decided to pursue its strategy of Recover), and a payoff of 4 is better than 2 (if the U.S. decided to pursue its strategy of No Recover). Likewise, against global insurgents, it is always better for the U.S. to follow its strategy of Recover, since a payoff of 3 is better than 1 (if the enemy decided to pursue his strategy of Capture), and a payoff of 4 is better than 2 (if the enemy decided to pursue his strategy of No Capture). The pure-strategy Nash equilibrium is (3 , *3*).

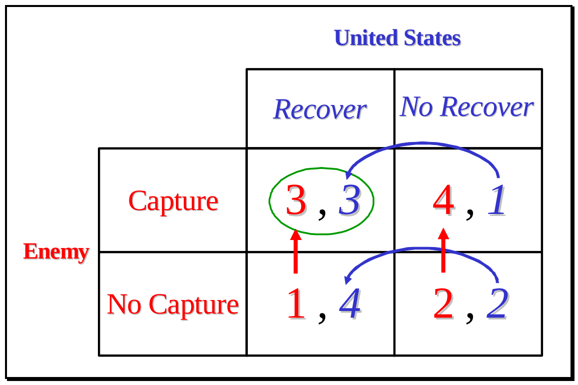

Figure 48. Analysis of PR Payoff Matrix: Globally Focused Insurgent versus the U.S.

Since this game has a unique Nash equilibrium, one must again evaluate the feasible region in figure 49 to determine if (3 , *3*) is PO. Figure 50 shows the reduced feasible region after eliminating all solutions with a value less than 3, or those solutions left of and below lines representing both players' security levels. The circled point represents the game's Nash equilibrium of (3 , *3*). Just as it was visually apparent in PR scenario 4, the unique Nash equilibrium in figure 50 is PO; there is no other outcome that gives both players higher payoffs, or gives one player the same payoff and the other player a higher payoff.

While the U.S. would prefer to obtain its highest payoff of 4, this is again unattainable when playing the game noncooperatively. Ultimately, if either player were to change his respective strategy of Capture or Recover (3 , *3*), the payoff to the player who moved to either (4 , *1*) or (1 , *4*) would decrease from 3 to 1. There are no benefits to departing (3 , *3*) because the player pursuing his respective strategy of No Capture or No Recover would lose two units of payoff, punish himself with his least preferred payoff of 1, and give one unit of additional payoff to his opponent. Assuming the other player does not deviate from his dominant strategy, this situation deters players from selecting anything other than dominant strategies.

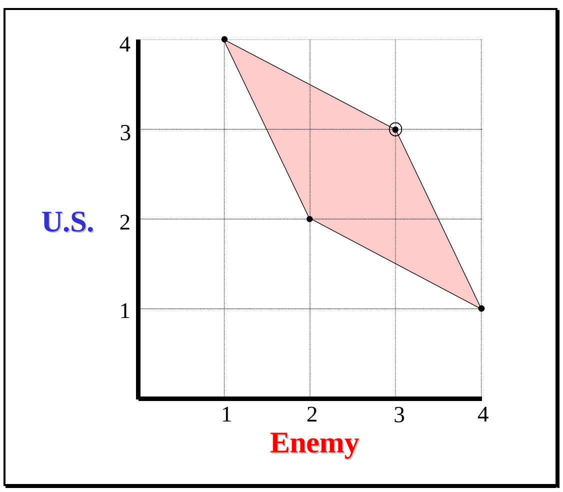

Figure 49. Feasible Region of Solutions (Globally Focused Insurgent versus the U.S.)

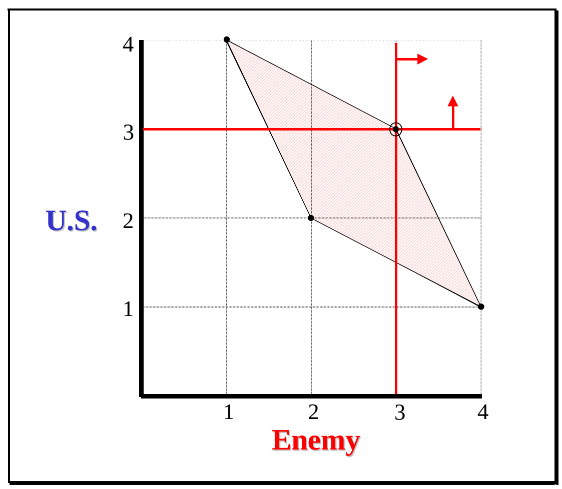

Figure 50. Reduced Feasible Region (Globally Focused Insurgent versus the U.S.)

Analysis of PR Scenario 7: Criminal Element or Organization

Applying the minimax theorem to the seventh game from chapter 3 (see figure 19) results in the maximin analyses shown in figures 51 and 52. Following its maximin strategy of Recover, figure 51 shows that the U.S. could do no worse than 3, but if following a strategy of No Recover, the U.S. could receive its worst possible outcome of 1. Likewise, figure 52 shows that by following a maximin strategy of No Capture, the enemy would guarantee himself an outcome of at least 2, while risking an outcome of 1 if he were to follow his strategy of Capture. The value of the game and the security level is 3 for the U.S. and 2 for the criminals.

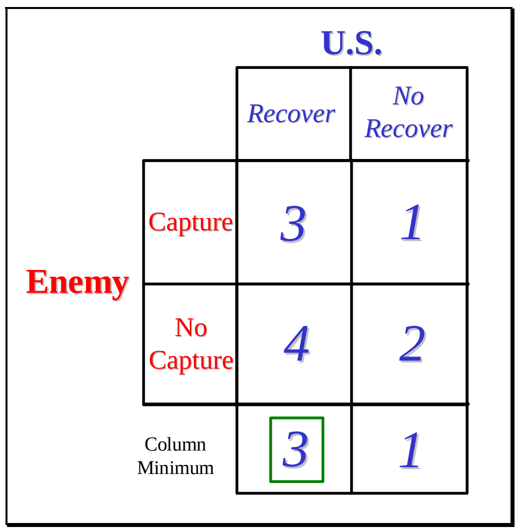

Figure 51. U.S. Maximin Strategy Selection of Recover

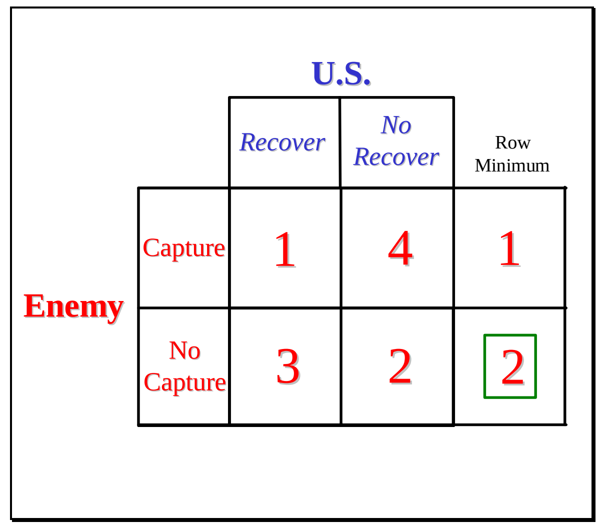

Figure 52. Criminal Organization Maximin Strategy of No Capture

When combined, both players' maximin strategies corresponding to No Capture and Recover intersect at the payoff strategy space (3 , *4*). As is shown in figure 53, following maximin strategies in this example results in a moderately stable outcome. It is only moderately stable because when playing maximin strategies, only the U.S. is following its dominant strategy; the criminal organization has no dominant strategy. In all cases, it is better for this U.S. to follow its strategy of Recover, since a payoff of 3 is better than 1 (if the criminal organization decided to pursue its strategy of Capture), and a payoff of 4 is better than 2 (if the criminal organization decided to pursue its strategy of No Capture).

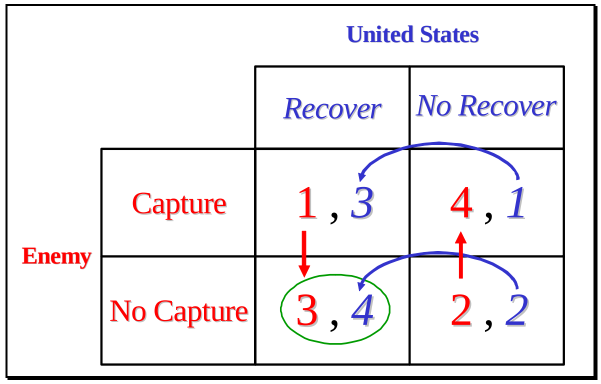

Figure 53. Analysis of PR Payoff Matrix: Criminal Organization versus the U.S.

For the criminal organization, however, its optimal strategy depends on what strategy it thinks the U.S. will follow. If the criminals determined the U.S. would prefer its strategy of Recover, a criminal would do better by following his strategy of No Capture since a payoff of 3 is better than 1. If the criminals determined the U.S. would prefer its strategy of No Recover, the criminals would do better when following a strategy of Capture, since a payoff of 4 is better than 2. Since criminals would correctly deduce that the U.S. would act rationally to secure either of its two most preferred payoffs of 3 or 4, the criminals would actually need to consider only outcomes associated with the dominant U.S. strategy of Recover. When the U.S. follows its strategy of Recover, the criminal organization would secure the higher of his remaining payoffs by following his strategy of No Capture. The pure-strategy Nash equilibrium is (3 , *4*).

Since there is a unique Nash equilibrium, one must evaluate the feasible region to determine if (3 , *4*) is PO. The highlighted area within figure 54 represents the feasible region of solutions, while figure 55 shows the reduced feasible region after graphing the U.S.'s security level of 3 and the criminals' security level of 2, and eliminating solutions left of and below those levels. Once again, the unique Nash equilibrium is PO. As shown in figure 55, there is no other outcome that gives both players higher payoffs or gives one player the same payoff and the other player a higher payoff than the point (3 , *4*).

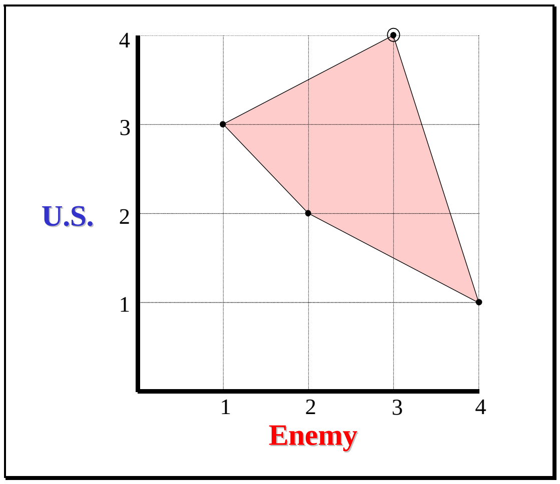

Figure 54. Feasible Region of Solutions (Criminal Organization versus the U.S.)

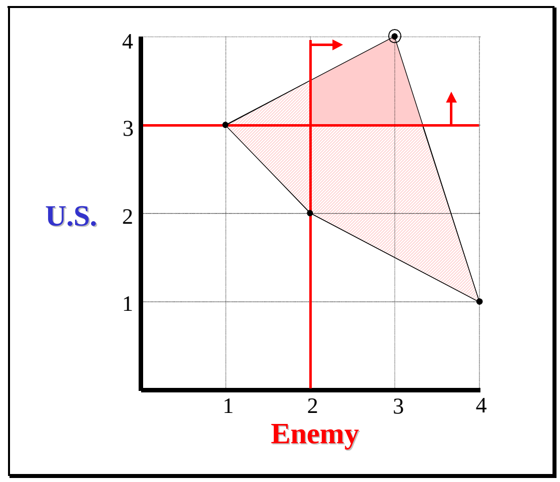

Figure 55. Reduced Feasible Region (Criminal Organization versus the U.S.)

Having already achieved its highest payoff of 4, the U.S. would have no incentive to vary its strategy. If the U.S. were to change it strategy of Recover (3 , *4*) to No Recover, the resulting payoff of (2 , *2*) would decrease the enemy's payoff by one, and would accordingly reduce the U.S.'s payoff by two. If the criminal organization were to change it strategy of No Capture (3 , *4*) to Capture, the resulting payoff of (1 , *3*) would lower the U.S.'s payoff by one while decreasing its own payoff by two. There is no benefit to departing from the equilibrium point, because the player who changes strategies loses two units of payoff, while only reducing his opponent's payoff by one unit. This loss deters both players from moving away from the Nash equilibrium, assuming the other player does not deviate from his dominant strategy.

Summary of PR Scenario Analyses

Reminded that no adversary is so unique that he does not fit, to some extent, into one of the seven categories analyzed in this chapter, there appear to be some noteworthy trends in the research. Most significantly, one could solve each of the seven scenarios applying pure-strategy solutions, and every scenario had a Nash equilibrium solution. Additionally, after analyzing all seven scenarios from the U.S. perspective, there was only one instance where the optimal strategy was No Recover (against a first-rate adversary) and only one case where the U.S. had no dominant strategy (against a second-rate adversary). From the perspective of the various adversaries, only the criminal organization's scenario produced either an optimal strategy of No Capture or a scenario with no dominant strategy. Only one scenario featured an outcome that was non-Pareto optimal (against a first-rate adversary), which happened to also model the prisoner's dilemma. Finally, two scenarios were constant-sum (equivalently zero-sum) games, resulting in a situation where all outcomes were PO (against a second-rate adversary and locally focused insurgents).

Analysis of the Cuban Missile Crisis Vignette

One can evaluate the Cuban missile crisis in the same manner as the previously discussed PR scenarios. Applying the minimax theorem to this situation produces the maximin analyses shown in figures 56 and 57. If the USSR were to follow its maximin strategy of Depart, figure 56 shows that it could do no worse than 2, but if following a strategy of Defend, the Soviets could have received their worst possible outcome of 1.

Likewise, if it were to follow its maximin strategy of Blockade, figure 57 shows that the U.S. would have guaranteed itself an outcome of at least 2, while following a strategy of Strike risked an outcome of 1. The value of the game and the security levels are 2 for both the U.S. and the Soviets. Unlike the previous scenarios evaluated, a security level of 2 leaves three possible solutions open for consideration versus the typical one or two solutions satisfying the requirement for a security level equal to or greater than the value of the game.

		USSR	
		Depart	*Defend*
U.S.	Block	*3*	*4*
	Strike	*2*	*1*
	Column Minimum	$\boxed{2}$	*1*

Figure 56. USSR Maximin Strategy Selection of Depart

		USSR		
		Depart	*Defend*	Row Minimum
U.S.	Block	3	2	$\boxed{2}$
	Strike	4	1	1

Figure 57. U.S. Maximin Strategy Selection of Blockade

Combining both players' maximin strategies corresponding to Blockade and Depart reveals an intersection at the payoff strategy space (3 , *3*). As figure 58 depicts, following maximin strategies in the Cuban missile crisis would have resulted in a highly unstable outcome. If both players were playing conservatively, the maximin solution could work, but the outcome of (3 , *3*) would have been extremely unstable because the incentive for either player to take advantage of a conservative player is problematic.

Assuming conservative and noncooperative play had resulted in a U.S. blockade and a Soviet withdrawal (3 , *3*), both players would have been tempted to cheat and choose their more aggressive strategies. If the U.S. had unilaterally changed its strategy to Strike, its outcome would have improved (4 , *2*); if the Soviets had unilaterally changed strategies to Defend, its outcome would have improved (2 , *4*). The absence of a dominant strategy for either player is partially to blame for this dilemma.

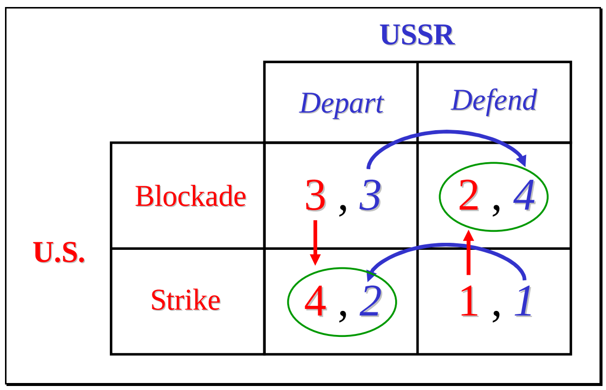

Figure 58. Analysis of the Cuban Missile Crisis Payoff Matrix

Another cause for the predicament inherent with the game of chicken is the strategic first move when players are not playing the game conservatively. In all cases, it would be beneficial for players to move first and secure their most preferred payoff. If the U.S. were to sever communications after seizing the initiative by choosing its precision Strike strategy, the Soviets would prefer to Depart instead of retaliating with their nuclear missiles and risking their least preferred payoff of 1. Likewise, if the Soviets were to move first and use their Defend strategy to secure their most preferred payoff, the U.S. would prefer its strategy of Blockade in lieu of risking a nuclear war's payoff of 1 through a precision nuclear retaliation. These strategic first move options directly relate to the two pure-strategy Nash equilibriums in the game of chicken, located at the points (2 , *4*) and (4 , *2*). If played uncooperatively, the likely outcome will be in one of these two strategy spaces, dependent upon which player moves first.

Even with two Nash equilibriums in the game of chicken, one can still evaluate the two solutions to determine if they are PO. The highlighted area within figure 59 represents the feasible region of solutions to the game of chicken. Figure 60 shows the reduced feasible region of solutions after graphing both security levels of 2 and eliminating solutions left of and below those lines. As it turns out, both Nash equilibriums and the compromise solution of (3 , *3*) are all PO. As figure 60 shows, from any one of those three points, there is no other outcome that gives both players higher payoffs or gives one player the same payoff and the other player a higher payoff.

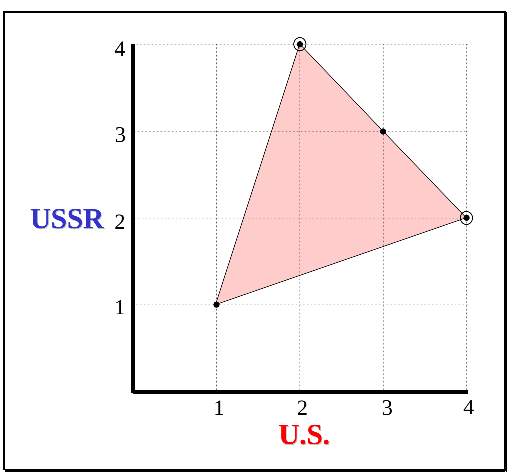

Figure 59. Feasible Region of Solutions (Cuban Missile Crisis)

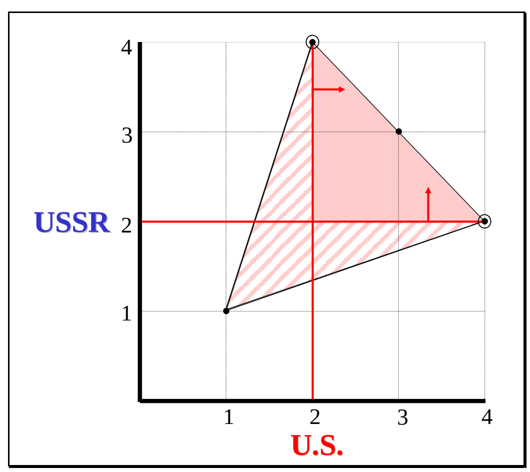

Figure 60. Reduced Feasible Region (Cuban Missile Crisis)

Once either player secures his most preferred payoff of 4, that player would have no incentive to move to the compromise outcome if playing in a noncooperative manner. If that player were to compromise, he would decrease his own payoff by one and increase his opponent's payoff by one. Playing noncooperatively, there is no benefit to choosing the strategies of Depart or Blockade, yet the crisis ended with these strategy selections. Recall that players in two-person variable-sum (partial-conflict) games can benefit from cooperation, but may have strong incentives not to do so. In the case of the Cuban missile crisis, the overwhelming incentive to preclude a nuclear war arguably spurred a mix of cooperative and noncooperative behaviors. The reasoning behind the compromise solution exists in the strategic moves of threats and promises discussed in chapter 2.

Given the U.S. desired either of its two most preferred strategies, both secured with the Soviet Depart strategy, the U.S. could have chosen to issue a threat to persuade the Soviets not to select Defend. By threatening to choose Strike if the Soviets chose Defend, the U.S. hoped that the fear of a (1 , *1*) payoff would result in a Depart strategy selection. This meets game theory's definition of a threat because if the Soviets chose Defend, a payoff of (1 , *1*) would be harmful to both players as compared to the alternative of (2 , *4*). However, this threat was not believable because if it had not deterred the Soviets from selecting Defend, there would have been no credible incentive to carry out the threat. Once the Soviets had made their selection of Defend, they would be inclined to believe that the U.S. would secure the better remaining outcome of 2 and give the Soviets their most preferred outcome of 4 regardless. When compared to their payoff of (2 , *4*) when complying, the Soviets quickly rationalized that selecting Depart would result in a payoff of (4 , *2*)--two units of payoff worse than the likely outcome when ignoring the threat. This threat alone would not achieve the desired effect.

Another possible strategic move to persuade the Soviets to select Depart would have been through a promise. By promising to follow Blockade if the Soviets selected Depart, the U.S. hoped that by forfeiting the opportunity to select its more preferred strategy would convince the Soviets to choose Depart. This meets game theory's definition of a promise because if the Soviets chose Depart, a payoff of (3 , *3*) would be harmful to the U.S. and beneficial to the Soviets, considering the alternative of (4 , *2*). Like the threat, this promise would not have been credible because the promise payoff of (3 , *3*) would have been worse for the Soviets than their likely payoff of (2 , *4*) when selecting Defend. Additionally, when considering what the U.S. would do once the Soviets had already selected Depart, the Soviets would arguably expect that the U.S. would renege on its promise in order to secure the better remaining outcome of (4 , *2*). The effect of trusting this promise is believed to be a payoff of (2 , *4*), which is two units of payoff worse than the Soviets could guarantee themselves by choosing Defend. This promise alone would not achieve its desired effect.

Given that a particular threat or promise is not effective when applied as the solitary means to an end does not imply that one cannot achieve the desired effect when combining the two strategic moves. Essentially, the conjoined effects of a threat and promise in the game of chicken must remove the appeal of choosing either of the Nash equilibriums. Since the threat would not convince the Soviets to choose Depart out of concern that the U.S. would capitalize on the opportunity to move to the Nash equilibrium point (4 , *2*), a believable U.S. promise to select (3 , *3*) could remove this doubt. With the option of (4 , *2*) now "eliminated" as a possible choice, the U.S. would also have to convince the Soviets that the U.S. would actually select Strike if the Soviets chose Defend. With the assistance of a promise, a credible threat "removes" the Nash equilibrium point (2 , *4*) from the possible choices. The combination of these strategic moves would make the strategy choices resulting in (3 , *3*) look much more attractive to the Soviets, considering the remaining alternative of (1 , *1*).

To illustrate the use of threats and promises in the Cuban missile crisis, the author will show a sequence of events that supports the use of strategic moves. Admittedly, there will never be an indisputable account of Kennedy's or Khrushchev's rationales for their decisions during those fourteen days, but game theory can offer one plausible explanation. As Brams recounts from his research, "several of President Kennedy's advisers felt very reluctant about initiating an attack against Cuba without exhausting less belligerent courses of action that might bring about the removal of the missiles with less risk and greater sensitivity to American ideals and values. Pointedly, Attorney General Robert Kennedy claimed that an immediate attack would be looked upon as 'a Pearl Harbor in reverse, and it would blacken the name of the United States in the pages of history'" (Brams 2001).

After seven days of guarded and intense debate within the upper echelons of government, Kennedy decided to impose a naval quarantine around Cuba. On 22 October 1962, Kennedy announced to the public the discovery of the missile installations and his decision to isolate the island. Since international treaties considered a blockade to be an act of war, this choice of words was deliberate. Kennedy further demanded that the Soviets remove all of their offensive weapons from Cuba and stated, "it shall be the policy of this nation to regard any nuclear missile launched from Cuba . . . as an attack by the Soviet Union . . . requiring a full retaliatory response" (Larson and Wiersma 1997, 14). From Kennedy's perspective, a maximin strategy choice of Blockade demonstrated his desire to play the game conservatively by giving the Soviets a way out of the crisis. Understanding the preferred strategy for the Soviets would be to Defend if the U.S. chose Blockade, Kennedy's threatening statements arguably served as an indicator of his willingness to escalate the crisis to nuclear war (1 , *1*) if the Soviets opted to Defend.

As previously explained, this threat alone would not be believable. On 23 October, Khrushchev instructed ships bound for Cuba not to stop at the quarantine, set to take effect at 10:00 AM (EST) on 24 October, and responded to Kennedy saying that the U.S.'s actions "may lead to catastrophic consequences for world peace" (Larson and Wiersma 1997, 15). The Soviets signaled their preference for the payoff of (2 , *4*). This notwithstanding, on 24 October, Khrushchev showed his unwillingness to expand the crisis by challenging the U.S. ships when at 10:25 AM Soviet ships turned away from Cuba. Khrushchev also sent Kennedy a letter showing he understood the threat, "You, Mr. President, are not declaring a quarantine, but rather are advancing an ultimatum and threatening that if we do not give in to your demands [(3 , *3*)] you will use force [(1 , *1*)]" (Larson and Wiersma, 16-17). Khrushchev needed a guarantee that the U.S. would not try to secure an outcome of (4 , *2*) if he decided to Depart. In a letter to Kennedy translated by 9:00 PM on 26 October, Khrushchev proposed removing his missiles if Kennedy would publicly announce never to invade Cuba--a credible U.S. promise to stay at (3 , *3*) if the Soviets chose Depart (Larson and Wiersma, 20).

By the morning of 26 October, Kennedy had begun to believe that the quarantine alone would not get the missiles out of Cuba and that only an invasion or a trade would eventually succeed. Through secret parallel negations between Soviet Ambassador Anatoly Dobrynin and Robert Kennedy earlier that same day, the president made promises to "examine favorably the question of [American Jupiter missiles in] Turkey," which the Soviets credited as justifying the missiles in Cuba (Larson and Wiersma 1997, 20). On 27 October, after the U.S. lost a U-2 over Cuba and committed other severe reconnaissance missteps, Khrushchev sent a more demanding letter that he also publicly broadcasted, proposing, "We are willing to remove from Cuba the means which you regard as offensive. . . .Your representatives will make a declaration to the effect that the United States . . . will remove its analogous means from Turkey. . . .And after that, persons entrusted by the United Nations Security Council could inspect on the spot the fulfillment of the pledges made" (Larson and Wiersma, 22).

While the strategic value of the unreliable missiles in Turkey was much less than the Cuba-based missiles, the public release of this proposal presented Kennedy a dilemma. As Kennedy stated, "We can't very well invade Cuba with all its toll when we could have gotten the missiles out by making a deal on the same missiles in Turkey" (Larson and Wiersma 1997, 23). Kennedy's comment about his missiles in Turkey seemingly made the likelihood of a U.S. move to (4 , *2*) that much more remote if the Soviets had decided to Depart; this signaled a Soviet desire to end the crisis at (3 , *3*), albeit at a higher price for the U.S. than simply promising not to invade Cuba. Kennedy then used his brother's parallel negotiations to broker a secret deal to quietly remove the Jupiter missiles a few months after the crisis, and warned that this pact could not be part of the public dialogue. Robert Kennedy then established a vague deadline to accept the secret deal, stating only that the U.S. needed a commitment by the following day instead of specifying an exact time on 28 October (Larson and Wiersma, 24).

Twenty minutes later, Kennedy released his official response to the Soviets' latest proposal, stating "The key elements of your proposals—which seem generally acceptable . . . 1. You would agree to remove [the missiles] from Cuba under appropriate United Nations observation and supervision . . . 2. We . . . would agree upon the establishment of adequate arrangements through the United Nations, to ensure the carrying out and continuation of these commitments (a) to remove promptly the quarantine measures now in effect and (b) to give assurances against the invasion of Cuba" (Larson and Wiersma 1997, 24-25). The United Nations inspections would be necessary to convince both sides that there would be no temptation to cheat, thus making the threats and promises believable and enforceable by a neutral third party.

While in a meeting deliberating a Soviet decision, Khrushchev received notification that Kennedy would make an address to his nation at 5:00 PM on 28 October. Fearful that Kennedy's address would be to announce an invasion of Cuba, the collective rapidly drafted a letter to accept Kennedy's agreement and hoped it would reach the president before the address. The Soviets apparently believed the ultimatum Robert Kennedy reiterated to Dobrynin a day earlier, stating "If you do not remove those bases, we w[ill] remove them" (Larson and Wiersma 1997, 24), again threatening to accept a payoff of (1 , *1*) if the Soviets chose to Defend. The Soviets were also confident that the U.S. would uphold its promise not to change its strategy to Strike.

The crisis phase ended when the president received the Soviet acceptance at 9:00 AM, and immediately broadcasted a confirming response over the Voice of America. The precise conditions of the 28 October agreement came in later negotiations, and United Nations inspection teams eventually monitored the removal of the missiles and the demolition of the missile bases in Cuba. The Soviet Navy shipped the missiles back to the USSR on the decks of its ships so that U.S. reconnaissance aircraft could physically observe and confirm quantities (Larson and Wiersma 1997, 27). Soviet promises to remove all offensive weapons also resulted in the removal of Soviet light bombers in Cuba by 21 November (Brams 2001; Larson and Wiersma, 27).

Only through a combination of several threats and promises was the compromise outcome of (3 , *3*) obtained. While the strategies associated with compromise in a game of chicken do not correspond to any Nash equilibrium, this example illustrates the use of strategic moves to influence the outcome of a game with no dominant strategies or games where maximin strategies do not yield a point of equilibrium. This example should also reinforce the notion of just how difficult it can be to avoid a Nash equilibrium outcome that is PO. While the U.S. seemingly won the game by achieving its immediate goal, the Soviets also won by gaining security for Cuba and having U.S. missiles in Turkey removed. Others may interpret winners and losers in this game by analyzing factors such as who swerved first, degrees of swerving, whether swerving after the other side had already swerved was an equivalent "loss," or whether swerving first actually result in a "win." Regardless of the method of interpretation, both sides arguably won by avoiding a nuclear showdown.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This purpose of this thesis was to determine if the PR community is using the most rational decision-making model to offset the predictability of traditional PR activities based on a report of the physical location of an evading IP, given the COE and the recent increase in asymmetric tactics to counter the U.S.'s conventional military superiority. From the analysis conducted in chapter 4, interpretation of the research evidence yields answers to the five secondary questions that answer the primary question and support the conclusion.

The first secondary question spoke to the feasibility of PR planners using game theory as a tool to assist with strategic problem solving and the MDMP. Paragraph four of a commander's estimate of the situation (comparison of own COAs) uses a decision matrix to record and compare advantages and disadvantages for each of a commander's COAs only with respect to predetermined evaluation criteria. Paragraph three of a commander's estimate (analysis of opposing COAs) determines the probable effects of enemy capabilities on the success of each of the commander's own COAs. No portion of the commander's estimate directly compares opposing COAs, let alone operationalizes the outcome of every combination of opposing COAs. Game theory, however, offers a logical way to present all of the data required to make a decision, and a methodology for solving the tactical problem. Commanders should base the decision as to which COA promises to be the most successful in accomplishing the mission on a more methodical comparison of opposing friendly COAs in relation to enemy COAs. As a strategic decision-making tool, game theory provides a way to graphically represent and compare information related to strategic preferences.

The second secondary question asked which game methodology, variable-sum or zero-sum, is better for analyzing strategic choices for a given PR scenario. As was shown in the analysis chapter, the variable-sum methodology is a more appropriate and precise representation of actual PR situations because one player's gain did not necessarily correspond with an equivalent loss by the other player. Considering all combinations of strategy choices in all seven scenarios, there were few instances where one player’s gain equally balanced an equivalent loss to the other player. Only in PR scenarios 2 and 5 were the equivalent of zero-sum games modeled by analyzing player preferences; all outcomes for these two scenarios were PO. In the other five PR scenarios, variable-sum game methodology supplied more appropriate and specific models of strategic choices for the given scenario. While the variable-sum game methodology initially requires more analysis and critical thinking to determine and assign values to the payoff matrix, this methodology lends itself to a more precise and useful decision-making tool for PR planners.

The third secondary question asked if it would be possible to determine different types of adversaries that the U.S. would likely face in the COE. Based largely on a combination of generalized motives and capabilities with regard to capturing IP, the author identified seven categories or types of adversaries. The previously identified weakness of placing adversaries into generalized categories for analysis is that it did not take into account the specific group characteristics that distinguish one group from another. Additionally, generalizing across cultural and regional idiosyncrasies did not do justice to the level of detailed analysis that is required to optimally exploit the advantages offered by focused analysis for a specific adversary. However, by assigning ordinal values to represent strategy preferences for each type of adversary, based on the organization's capabilities, ideology, motivations, and strategy with regard to IP, the author determined generalized preferences given the two available COAs.

Possibly the greatest advantage offered to PR planners who choose to use game theory methodology is that game theory is highly adaptable to the precise results of a thorough analysis of the enemy. The payoffs are not fixed, they can be changed or modified, and can be updated with the stroke of a pen. Assuming that a PR planner could transcend cultural, cognitive, or perceptual bias in order to determine preferences for COAs from that adversary's perspective, the specific application of game theory to the particular characteristics of any given adversary supports fighting the enemy's strategy instead of "fighting the plan." Adaptability is a strength of game theory because PR planners can easily modify payoff matrices to reflect improved situational understanding, warranting changes in the order of preferences.

The fourth secondary question centered on the problem of how to determine reasonably accurate utility values necessary to apply utility theory to a variable-sum, partial-conflict game representative of a PR scenario. In order to apply a meaningful mixed-strategy solution to a PR scenario not solvable with pure strategies, one must determine cardinal values for both players' preferences. Based on the analysis in chapter 4, all seven of the PR scenarios had at least one player with a dominant strategy, and no fewer than one Nash equilibrium solution. Under such circumstances, there was no requirement to determine cardinal values needed to apply utility theory to the game theory methodology. This said, the recommendation section of this chapter highlights the need for follow-on research to determine a quantitative scale of military worth that is the same for both players in a PR scenario. Determining a uniform scale of military worth would make PR game theory analysis that much more precise and useful to strategic decision makers.

The last secondary question built upon the fourth by asking if there were any PR scenarios not solvable with pure or mixed strategies where determining a Nash arbitration solution might be useful for PR planners. Since all seven PR scenarios were solvable using pure strategies, there was no need to consider this alternative during analysis. Furthermore, if such a scenario had existed, determining how to fill the role of the arbitrator needed to schedule each player to select his PR strategies in the correct proportions and at the right times in order to achieve the Nash arbitration solution would be difficult at best. The most likely PR scenario where one could feasibly apply arbitration would be a non-Pareto optimal situation involving an atypical criminal organization with uncharacteristic preferences when compared to the generalized preferences for criminal elements derived in this research.

As presented in the analysis chapter, the U.S. guarantees itself either of its two most favorable outcomes by attempting to recover IP in PR scenario 7, so there would be little incentive to negotiate with a criminal element unless the desire is to supplement or broaden existing recovery options. Nevertheless, with no Nash equilibrium solution, and given a criminal element’s overriding desire to increase personal wealth and status, the U.S. could choose to “employ” such elements as a part of the U.S. recovery architecture via clandestine or covert negotiations. While this scenario does not take into account the legal or moral considerations of dealing with insalubrious elements within a target nation, it is still a viable method of effecting recovery. Though essentially "capturing" IP in support of the U.S.'s recovery architecture, a criminal element would still want to guard against engaging local military, police, and insurgent groups in its attempts to reach IP first. This notwithstanding, criminals working in conjunction with the U.S. would now have the added incentive of virtually guaranteed personal wealth by secretly cooperating with covert or clandestine U.S. government "arbitrator" agents. In order to apply this strategy, PR planners would first calculate prudential strategies by assigning cardinal values to all ordinal preferences before calculating the Nash arbitration solution.

The answers to these secondary questions support the conclusion that the PR community is indeed using the most rational decision-making model in conducting PR when given a report of isolation and the physical location of evading IP. Even considering the COE and the recent increase in asymmetric tactics to counter the U.S.'s conventional military superiority, the tactical costs incurred through the PR community's predictability in its traditional recovery activities outweigh the strategic costs of not attempting to recover IP in all but one of the PR scenarios. In this one scenario against the first-rate adversary, the PR community still chooses the most rational strategy selection. In reality, however, the PR community mitigates risks to traditional RFs against such foes by adding another strategic option to the equation--covert and clandestine recovery operations conducted by SOF and other government agencies. This is a logical and rational response to the threat inherent in attempting traditional recovery methods against an adversary with comparable capabilities.

The summation of the analysis conveyed in this thesis may initially seem counterintuitive. Immediately assembling, organizing, and launching an ad hoc RF to preclude capture and exploitation does afford adversaries an easily exploitable opportunity to take advantage of the U.S.'s predictability, but the basis for this reasoning rests largely on tactical-level considerations. While one could argue that the U.S. military can no longer afford to offer an easily exploitable opportunity to its adversaries pursuing asymmetric tactical advantages, the process used to decide under what conditions one should launch an RF is of a strategic nature.

The seemingly instinctive response of launching RFs that are knowingly vulnerable to deception operations designed to bait them into an ambush, is more often than not the optimal strategic choice based on a generalized adversary's capabilities, ideology, motivation, and strategy. The potential propaganda value of IP, when coupled with an adversary's IO campaign to attack the U.S.'s legitimacy and credibility and the perception that the U.S. is in control of that situation, might offer an adversary the highest probability of attacking the will of the American public. Given the reality of such a potentially devastating and seemingly strategic vulnerability, the U.S. can ill afford not to recover IP. In this strategic context, the MDMP with regard to PR is completely rational.

Recommendations

Based on the findings of this thesis, the author recommends the following:

1. The military should continue to explore other options to facilitate PR. While nonconventional assisted recovery (NAR) and unconventional assisted recovery (UAR) have provided other means of recovery, these methods should receive much more emphasis in four general scenarios: urbanized areas where the use of traditional recovery

assets are impractical; countries now considered possible second-rate adversaries that are pursuing efforts to modernize their militaries; under governed areas in countries with minimal U.S. military presence where no traditional recovery platforms are available; and countries now considered potential first-rate adversaries which threaten regional stability. NAR and UAR recovery mechanisms take much time to establish and cannot be created overnight; this will require careful analysis as to the most likely adversaries the U.S. will face in the next ten to fifteen years, and possibly beyond.

2. The military should strongly consider the applicability of game theory to other military operations. While the PR mission may prove to be unique in its strategic context, game theory can provide military planners a useful methodology to compare and evaluate any combination of competing strategies. Using game theory to analyze any combination of opposing strategies at a particular decision point, for example, could offer a commander insight to his adversary's most rational strategy choice for the tactical problem at hand. The military should consider game theory's applicability to planners at all levels, military strategists, and other strategic decision makers, and should not rule out its use by tactical-level commanders who have sufficient time to thoroughly plan and war-game multiple COAs.

3. The U.S. military should dedicate considerable thought and effort to adapting the generalized categories developed in this thesis to specific organizations or adversaries. By developing precise models for specific situations, the military could determine an optimal PR SOP to conduct operations against a known adversary. A reliable assessment will require personnel who have the cultural and regional expertise to accurately determine an adversary's preference from that adversary's perspective.

Detailed and precise analysis offers planners a definitive advantage by significantly reducing the decision cycle of commanders and planners faced with a PR situation. Increasing decision superiority with regard to PR operations will directly support doctrine outlined in the DOD's recently published *Joint Operations Concepts*.

4. In an effort to create more precise models of recovery, the PR community should make a significant investment in determining a quantitative scale of military worth specific to PR. Determining a uniform scale of military worth that is the same for all players in a PR scenario will make the application of game theory noticeably more precise and considerably more useful to strategic PR decision making. Initial research on how to best develop this scale should focus on perceived probabilities of PR mission success based on force ratios or relative combat power, but this methodology becomes progressively less reliable progressing from PR scenario 1 to PR scenario 7. Quantifiable values for peer competitors are arguably easier to determine than values for adversaries using asymmetric tactics or techniques. Additionally, seemingly subjective metrics such as the worth of an adversary's leadership would be hard to quantify in a meaningful manner. This notwithstanding, the DOD should consider leveraging the knowledge, skills, and abilities of personnel serving in operations research and systems analysis organizations to initially operationalize a quantitative scale of PR-specific military worth.

5. While considering how to apply game theory to other military applications, DOD should not limit itself to zero-sum approaches. For the COE, and for most types of stability operations and support operations, applying variable-sum game theory methodology seems more appropriate, given that most situations do not involve strict winners and losers in a military context. There are arguably varying degrees of loss and

gain in such a complex operational environment. The zero-sum approach, while simpler to use and analyze, does not accurately depict varying degrees of strategic preferences more common in operations classified as small-scale contingencies or military operations other than war. The most preferred choice for the U.S. is not always the least preferred choice for the other side, and vice versa.

GLOSSARY

Cardinal utility or cardinal value. Numbers assigned in such a way that the ratio of differences is meaningful; a scale on which not only the order of numbers, but also the ratio of differences of the numbers is meaningful [interval scale]. For a mixed-strategy game solution to be meaningful, the numbers in the game matrix must be cardinal utilities (Straffin 1993, 50).

Chicken or game of chicken. A two-person variable-sum game in which each player has two strategies: to swerve to avoid a collision or not to swerve and possibly cause a collision. Neither player has a dominant strategy. The compromise outcome, in which both players swerve, and the disaster outcome, in which both players do not, are not Nash equilibria; the other two outcomes, in which one player swerves and the other does not, are Nash equilibria (COMAP 2003, 567).

Commander's estimate of the situation. A logical process of reasoning by which a commander considers all the circumstances affecting the military situation and arrives at a decision as to a COA to be taken in order to accomplish the mission (JP 1-02 2004, 103).

Constant-sum game. A game in which the sum of payoffs to the players at each outcome is a constant, which can be converted to a zero-sum game by an appropriate change in the payoffs to the players that does not alter the strategic nature of the game (COMAP 2003, 582).

Contemporary operating environment (COE). The operational environment existing today and for the clearly foreseeable future (out to the year 2020). The DOD defines an operational environment in JP 1-02 as "a composite of the conditions, circumstances, and influences that affect the employment of military forces and bear on the decisions of the unit commander" (FM 7-100.3 2004, iv-v).

Designated recovery forces. Personnel recovery-capable forces that can be tasked to conduct personnel recovery missions, although their primary mission and function may not be personnel recovery (JP 3-50 (second draft revision) 2004, GL-10).

Dominant strategy. A strategy that is sometimes better and never worse for a player than every other strategy, whatever strategies the other players choose (COMAP 2003, 582).

Dominated strategy. A strategy that is sometimes worse and never better for a player than some other strategy, whatever strategies the other players choose (COMAP 2003, 582).

Evader. Any isolated person who is eluding capture (JP 3-50 (second draft revision) 2004, GL-12).

Evasion. The process whereby isolated personnel avoid capture with the goal of successfully returning to areas under friendly control (JP 3-50 (second draft revision) 2004, GL-12).

Expected value (EV) or expected payoff. The expected value of a set of payoffs is the weighted average of those payoffs, where the weights are the probabilities that each will occur. Using the expected value principle, if player 1 knows that player 2 is playing a given mixed strategy, and will continue to play it regardless of player 1 does, player 1 should play a strategy that has the largest expected value [equalizing expectations]. The expected value of getting payoffs $a_1, a_2, \ldots, a_k$ with respective probabilities $p_1, p_2, \ldots, p_k$ *is* $p_1a_1 + p_2a_2 + \ldots + p_ka_k$ allows analysis of one or both players using mixed strategies (Straffin 1993, 13).

Game theory. A mathematical tool to study situations, called games, involving two ore more players with different values and goals, involved in conflict and/or cooperation (COMAP 2003, 544). The study of how players should rationally play games (Straffin 1993, 2).

Isolated personnel (IP). US military, DOD civilians, or DOD contractor personnel in support of a military operation that have become separated from their unit or organization in an uncertain or hostile environment or denied area requiring them to survive, evade, resist, or escape (JP 3-50 (second draft revision) 2004, GL-14).

Maximin. In a two-person game, the largest of the minimum payoffs in each row of a payoff matrix (COMAP 2003, 582).

Maximin strategy. In a two-person zero-sum game, the pure strategy of the row player corresponding to the maximin in a payoff matrix (COMAP 2003, 582).

Military decision-making process (MDMP). A seven-step planning model that establishes procedures for analyzing a mission, developing, analyzing, and comparing COAs against criteria of success and each other, selecting the optimum COA, and producing a plan or order. The MDMP application of thoroughness, clarity, sound judgment, logic, and professional knowledge to organize planning activities, share a common understanding of the mission and commander's intent, and develop effective plans and orders (FM 5-0 2005, 3-1--3-2).

Minimax. In a two-person zero-sum game, the smallest of the maximum payoffs in each column of a payoff matrix (COMAP 2003, 582).

Minimax strategy. In a two-person zero-sum game, the pure strategy of the column player corresponding to the minimax in a payoff matrix (COMAP 2003, 582).

Minimax theorem. The fundamental theorem for two-person constant-sum games, stating that there always exists optimal pure or mixed strategies that enable the two players to guarantee the value of the game (COMAP 2003, 582).

Mixed-strategy solution. A strategy that involves the random choice of pure strategies, according to particular probabilities. A mixed strategy is optimal if it guarantees the value of the game. A player would only use a mixed strategy when he is indifferent between several pure strategies, when keeping the opponent guessing is desirable, or when the opponent can benefit from knowing the next move (COMAP 2003, 582).

Nash arbitration scheme. A cooperative solution to a variable-sum game that recognizes the strategic bargaining position of each player, and is fair in the sense that from the status quo point, each player is awarded proportionally (the flatter the Pareto optimal [PO] boundary line, the more the row player is rewarded; the steeper the line, the more the column player is rewarded). All players agree to allow an arbitrator to determine a better outcome, and agree to play the mixed strategies according to the schedule set forth by the arbitrator [Nash solution] in the right proportions and at the right times to arrive at the Nash point (Straffin 1993, 102-110).

Nash equilibrium. A set of strategies and the corresponding payoffs with the property that no player can benefit by changing his strategy, given that the other player(s) do not depart from their strategies (COMAP 2003, 582). In 1950, John Nash proved that every two-person game has at least one equilibrium point in either pure or mixed strategies; point(s) of equilibrium in variable-sum games are referred to as Nash equilibrium in his honor source (Straffin 1993, 66).

Negotiation set. The set of (pure or mixed) outcomes that satisfy the conditions of being PO and located on the PO boundary at or above the security level for both players (Straffin 1993, 103).

Noncooperative game. A game where the players try to do the best for themselves by choosing strategies simultaneously, and with no communication between players (Straffin 1993, 65).

Ordinal scale or ordinal value. A ranking of a player’s outcomes from best to worst, where the high number generally equates to the greater the payoff. Ordinal values indicate an ordering [relative ranking] of outcomes from best to worst, but say nothing about the degree [absolute or relative magnitude] to which a player prefers one outcome over another [or the quantity being measured] (COMAP 2003, 563).

Outcome. The resulting scenario determined by the strategies each player chooses (Straffin 1993, 3).

Pareto inferior. An outcome of a game is non-Pareto optimal (or Pareto inferior or Pareto inefficient) if there is another outcome that gives both players higher payoffs, or gives one player the same payoff but the other player a higher payoff (Straffin 1993, 68).

Pareto optimal (PO). A measure of efficiency. An outcome of a game is PO if there is no other outcome that makes every player at least as well off and at least one player strictly better off. Players cannot improve on a PO outcome without hurting at least one player. Often, the Nash equilibrium in pure strategy is not PO, implying that all players can increase their payoffs employing a mixed strategy or Nash arbitration technique. In a zero-sum game, every outcome is PO, since every gain to one player means a loss to the other (Straffin 1993, 68).

Pareto optimal boundary, Pareto optimal line, or Pareto optimal line segment. The line segment(s) or point(s) within the negotiation set that meet the definition of PO, and are above the security level of both players (Straffin 1993, 68).

Partial-conflict game. A variable-sum game in which players can benefit by cooperation, but may have strong incentives not to cooperate (COMAP 2003, 582).

Payoff function. For the COAs selected by the players, this function represents the value of the outcome to the different players (Straffin 1993, 3). Also referred to as a payoff strategy space or pure-strategy space.

Payoff matrix. A rectangular array of numbers. In a two-person game, the rows and columns correspond to the strategies of the two players, and the numerical entries give the payoffs to the players when these strategies are selected (COMAP 2003, 582).

Personnel recovery (PR). The sum of military, diplomatic, and civil efforts to affect the recovery and reintegration of U.S. military, DOD civilians, and DOD contractor personnel who are isolated or missing while participating in a U.S.-sponsored military activity or mission. Additionally, when directed by the President of the United States or the Secretary of Defense, the DOD shall provide PR support to other governments, agencies, organizations, and individuals in accordance with all applicable laws, regulations, and memoranda of agreement or understanding (JP 3-50 (second draft revision) 2004, I-1 and GL-17).

Players. The people, organizations, or countries who are involved in either conflict or cooperation, and whose situation and choices game theory models (COMAP 2003, 544).

Preference. The idea that players prefer some outcomes to others (COMAP 2003, 544).

Prisoner's dilemma. A two-person variable-sum game in which each player has two strategies, cooperate or defect. Defect dominates cooperate for both players, even though the mutual-defection outcome, which is the unique Nash equilibrium in the game, is worse for both players than the mutual-cooperation outcome (COMAP 2003, 565).

Prudential strategy. In a variable-sum game where there are multiple equilibrium points that are non-equivalent and non-interchangeable or where there is a unique equilibrium point that is not PO, the optimal strategy for the row player will be the row player's prudential strategy. By playing a prudential strategy, the row player can assure that he will get at least his security level, which is the value of the game. This is similar to the zero-sum game concept of both players playing their cautious minimax strategies of maximizing their payoffs in the worst possible case. The column player's best response strategy to his opponent's prudential strategy is his counter-prudential strategy (Straffin 1993, 68-70).

Pure-strategy solution. A solution to the game [COA] a player can choose in a game that does not involve randomized choices [a definitive move or action that a player will follow in every possible attainable situation in a game] (COMAP 2003, 582).

Rational actor model or rational choice theory. A decision-making model that assumes largely unemotional, calculating, and risk-averse decision-makers seek to accomplish four tasks: accurately identify the problem that confronts them; take into account the key factors that bear on the problem; critically examine alternative COAs; and make a choice that will wisely maximize benefits and minimize costs. Rational behavior does not require behavior consistent with an outside value system, only on that is internally consistent. In assuming that Player A is acting rationally, one cannot superimpose Player A's own values onto Player B (Lenses of Analysis 2001).

Rational choice. A choice that leads to a preferred outcome (COMAP 2003, 583).

Recovery. Actions taken to recover and return isolated personnel to friendly control (JP 3-50 (second draft revision) 2004, GL-18).

Recovery force (RF). An organization consisting of personnel and equipment with the mission of seeking out evaders, contacting them, and returning them to friendly control (JP 3-50 (second draft revision) 2004, GL-18).

Saddlepoint. In a two-person constant-sum game, the payoff that results when the maximin and the minimax are the same, which is also the value of the game (COMAP 2003, 583). In games with saddlepoints, players' worst-case analyses lead to best guaranteed outcomes in the sense that each player can ensure that he will not do worse than the saddlepoint outcome, and may do better if the other player deviates from a maximin or minimax strategy (COMAP 2003, 549). If a two-person constant-sum game does not have a saddlepoint, the solution will be in mixed strategies (COMAP 2003, 578).

Security level. In a variable-sum game, the lowest level guaranteed by playing the game noncooperatively [pure-strategy solution]; neither player should be forced to accept less than what they could guarantee themselves by noncooperative play (Straffin 1993, 103).

Status quo (SQ) point. The intersection of the security levels in a two-person variable-sum game; both players can guarantee themselves at least this value by playing the game noncooperatively using respective pure-strategy solutions (Straffin 1993, 103).

Strategy. One of the COAs a player can choose in a game; strategies are mixed or pure, depending on whether they are selected in a randomized fashion (mixed) or not (pure) (COMAP 2003, 583).

Total-conflict game. A zero-sum or constant-sum game in which what one player wins, the other player loses, so cooperation never benefits the players (COMAP 2003, 545 and 583).

Two-person variable-sum game. A game scenario in which one player's gain does not necessarily correspond with an equivalent loss by the other, because some outcomes have net results greater or less than zero. If not equivalent to a zero-sum game, the interests of players in a variable-sum game are not strictly opposed, and not strictly coincident. The game will combine competitive aspects with some opportunities for cooperation (Straffin 1993, 65).

Two-person zero-sum game. A two-person constant sum game in which the payoff to one payer is the negative of the payoff to the other player, so the sum of the payoffs to the players at each outcome is zero (COMAP 2003, 583).

Utility theory. The science of assigning numbers to outcomes in a way that reflects an actor's preferences. A utility function for a given player assigns a number for every possible outcome of the game, with the property that a higher number implies that the outcome is more preferred. Utility functions may be either ordinal or cardinal (Straffin 1993, 49-50).

Value of the game. As provided by the minimax theorem, every m x n matrix game has a solution. That is, there is a unique number v, called the *value of the game*, and there are optimal (pure or mixed) strategies for both row and column players such that: 1) if the row player uses his optimal strategy, the row player's expected payoff will be $\geq v$, no matter what the column player does, and 2) if the column player uses his optimal strategy, the row player's expected payoff will be $\leq v$, no matter what the row player does (Straffin 1993, 18). In total-conflict games, the value is the best outcome that both players can guarantee. In games with saddlepoints, players can guarantee this outcome by choosing their minimax and maximin strategies (COMAP 2003, 549).

Variable-sum game. A game where the sum of all players' payoffs differs depending on the strategies they choose. In variable-sum games, players have some interests in common, which may lead to all players being better off through cooperation. Games of partial conflict are variable-sum games, in which the sum of payoffs to the players at the different outcomes varies (COMAP 2003, 561).

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